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M. EIFFEL.

GUSTAVO EIFFEL, author of the great Eiffel Tower, at Paris, is fifty-seven years of age, was born at Dijon, in 1832. He is no novice in the matter of huge engineering constructions.

He made the framework of Bartholdi's "Liberty," and executed the grand vestibule and the principal facade of the Paris exhibition of 1876, a work which came to three million francs.

One of his principal works is the bridge which he erected over the Douro, at Oporto, on the Lisbon railway, in 1876, which is, indeed, one of the finest specimens of engineering skill in Europe.

The river is spanned by a magnificent arch of 160 meters, at a height of 61 meters from the river, and is executed with a view to the artistic effect as well as its stability. This bridge cost a million and a half francs.

Another remarkable work of M. Eiffel is the railway viaduct of Garabit, over the valley of Truyere, in the middle of France, which cost 3,248,000 francs. Here the opening of the arch is 165 meters, and the height above the water 124 meters. He has also constructed some railway bridges and viaducts remarkable for their length, such as a bridge at Szeged, in Hungary, which is 606 meters long, and one at Vienna, in Portugal, which is 736 meters.

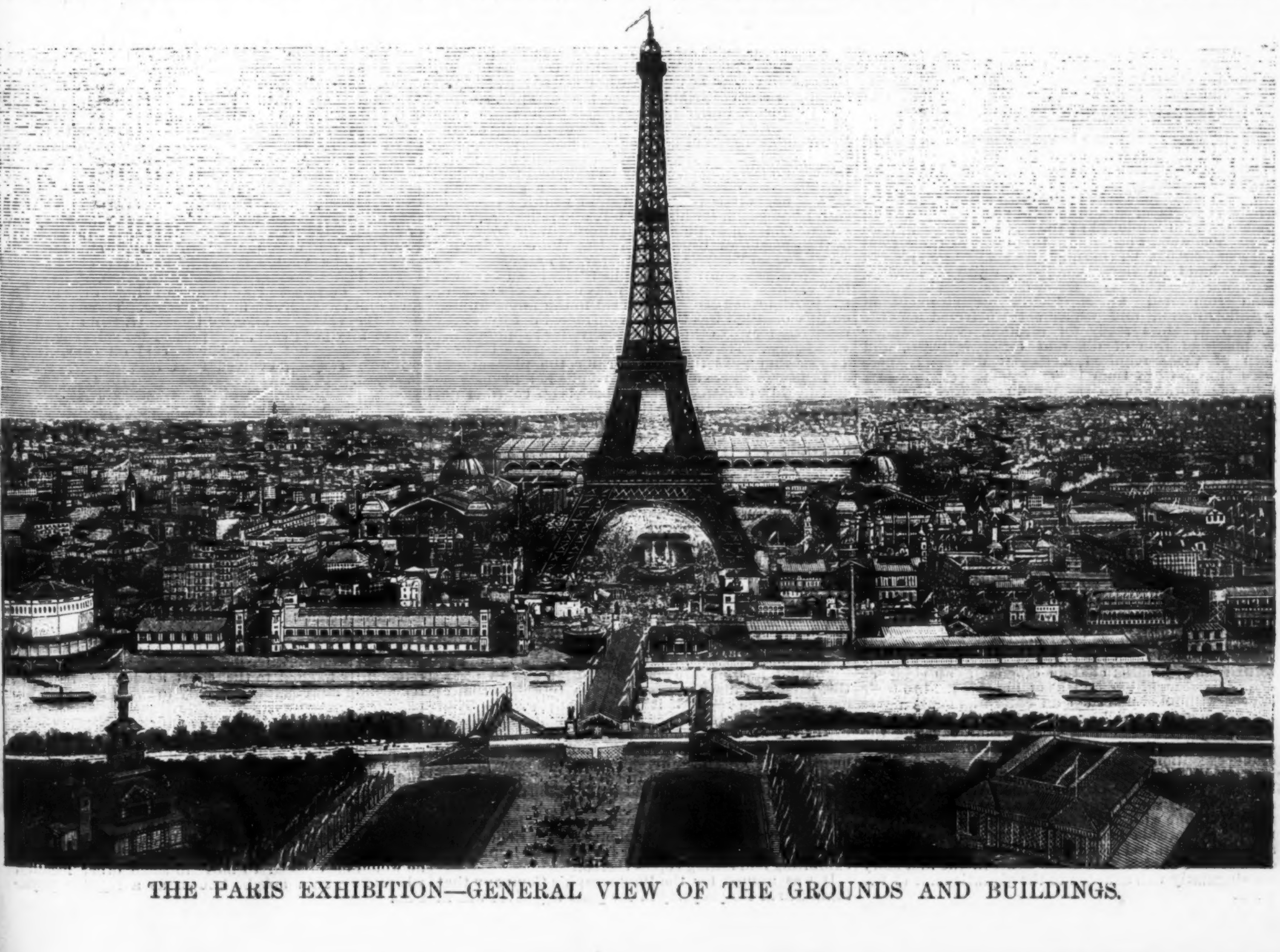
GUSTAVO EIFFEL, PROJECTOR OF THE EIFFEL TOWER, AT PARIS.

THE EIFFEL TOWER.

WE give herewith an engraving of this great work, for which we are indebted to *L'Illustration*, and from *Engineering* we gather the following particulars:

The Eiffel Tower is the natural development of the class of work upon which its constructor has been occupied for so many years; it was the direct outcome of a series of investigations undertaken by M. Eiffel in 1885, with a view of ascertaining the extreme limits to which the metallic piers of viaducts could be pushed with safety, this special line of investigation having reference to a proposed bridge with piers 400 ft. in height and 140 ft. of base. The idea of the great tower followed, preliminary plans were prepared, and calculations made by two of M. Eiffel's principal engineers, MM. Nouguier and Koechlin, and by M. Sauvestre, architect. Naturally the leading principle followed was that adopted by M. Eiffel in all his lofty structures, namely, to give to the angles of the tower such a curve that it should be capable of resisting the transverse effects of wind pressures without necessitating the connection of the members forming these angles, by diagonal bracing. The Eiffel Tower, therefore, consists essentially of a pyramid composed of four great curved columns, independent of each other and connected together only by belts of girders at the different stories, until the columns unite toward the top of the tower, where they are connected by ordinary bracing. Iron, and not steel, was used in the construction throughout.

There are four independent foundations, each standing at one angle of a square, about 330 feet on a side; the two piers nearest the Seine were known as numbers 1 and 4, those adjoining the Champ de Mars as 2 and 3. On the site of the two foundations 2 and 3, the bed of gravel was met with 23 ft. below the surface; the thickness at this point is about 18 ft. The conditions for obtaining a good foundation were therefore extremely favorable, and the piers were built upon a bed of



THE PARIS EXHIBITION—GENERAL VIEW OF THE GROUNDS AND BUILDINGS.

cement concrete 7 ft. in thickness. The two piers nearest the Seine required different treatment. The bed of sand and gravel was only met with about 40 ft. below the surface, that is to say, about 16 ft. lower than the mean water level of the Seine, and it was overlaid by soft and permeable deposits. Excavations were pushed, by means of caissons and compressed air, to a depth of about 52 ft. below the surface, and it was found that, under the gravel, variable deposits of fine sand, formed of limestone and sandstone, had accumulated, having been left there by the water after the clay had been washed out in hollows by the stream. Owing to this there existed a good and incompressible bed about 10 ft. thick under the western pier on the Grenelle side, and nearly 20 ft. thick under the north pier on the Paris side. Apart, therefore, from the difficulties in sinking for the foundations, the conditions were very satisfactory. The mode of sinking adopted was that of compressed air, with iron caissons 49 ft. 2 in. long by 19 ft. 8 in. wide; four such caissons were required for each pier, and they were sunk to a depth of 40 ft. below the surface, or 16 ft. lower than the Seine mean water level.

The tower terminates at a height of 896 feet above the ground, with a platform about 53 feet square. The width of the column at this level is 33 feet, the gallery being carried by brackets which are sufficiently wide to afford a considerable area of platform. It is almost unnecessary to state that this space is securely protected by a railing and glass to prevent any voluntary or involuntary catastrophe. Above the platform rises the campanile, which is of the design shown; in the lower part of this is established a spacious and very completely fitted laboratory, closed to the public and intended for the prosecution of scientific research and observation. Four latticed arched girders rise diagonally from each corner of the lower part of the campanile and unite at a height of about 54 feet above the platform. By means of a spiral staircase yet another gallery is reached, about 19 feet in diameter, and surrounding the lantern which crowns the edifice and brings the height of the structure to 984 feet. Above this rises the great lightning conductor. Within the lantern, which is 22 feet high, will be placed a very powerful electric light, placed within a lantern of the first order, and projecting white, blue, and red beams. Reflectors will throw these beams over Paris, and will help to illuminate the Champ de Mars.

Provision is made for protecting the structure from the effect of lightning by means of cast iron pipes, 19 inches in diameter, and passing through the water-bearing strata below the level of the Seine for a distance of 60 feet. At one end these pipes are turned vertically, and are connected with the ironwork of the tower. There are eight pipes in all, two for each column.

The total weight of wrought and cast iron that has been used in this unique structure is 7,300 tons, not including the weight of the caissons employed in the foundations nor the machinery installed for working the elevators.

No doubt during the period that the exhibition is kept open the ample facilities thus provided for the public will not be found excessive, but it is scarcely reasonable to suppose that after all the buildings on the Champ de Mars have been swept away, and the vast column alone remains to suggest the glories of the departed centennial celebration, great numbers of visitors will go so far out of Paris as the Champ de Mars to enjoy a sensation which by that time will have ceased to be novel. It is to be hoped that, by the time the exhibition closes, the enterprising syndicate which has acquired the Eiffel Tower will find themselves repaid to a large extent. Otherwise there is reason to fear that their speculation may not turn out profitable, and that their twenty years' concession will scarcely suffice to make their speculation a satisfactory one.

But of course the tower has other uses than that of money making, some uses which are now apparent, and others which the existence of the structure will suggest as time goes on.

We may conclude this notice with a few miscellaneous particulars of this interesting work. The total weight of iron employed in the structure itself is 7,300 tons. The weight of rivets is 450 tons, and their total number 2,500,000. Of this quantity 800,000 were riveted up by hand on the tower itself, during the work of fixing together the finished pieces which had been completed at M. Eiffel's establishment at Levallois-Perret, and which were delivered on the Champ de Mars ready for erection. The number of pieces of iron of different forms is 12,000, and each of these required a special drawing; there were thus no less than 12,000 working drawings sent into the workshop, to say nothing of the innumerable sketches and plans prepared before the final details were decided upon. The total thrust upon the foundations is 565 tons, not including the effect of wind, and 875 tons under a maximum wind pressure. The tower is painted of a rich chocolate color, the tone of which is lightened from the base toward the summit. The painting, which was of itself a considerable work, is very effective, especially when lighted by the sun. But little decoration has been attempted; it would have been wasted labor and expense. The level of the first story is marked by a bold frieze, on the panels of which, around all four faces of the tower, are inscribed in gigantic letters of gold the names of the famous Frenchmen of the century who have most contributed to the advancement of science.

"It is as it were under their patronage that this monument is erected, and the constructor has desired to consecrate to them the place of honor, and upon it to write their names in letters of gold, as an evidence of public recognition, and as of homage paid to their efforts, without which such an enterprise could never have been attempted."

Above this frieze the four-sided arcade, covering the exterior gallery, is elaborately decorated, and considerable exception has been taken to this feature as marring the bold and graceful outline of the tower. A similar arcade encircles the tower at the level of the second story, and the same objection may be raised with regard to it, but with less force, because the great height makes the arcade look insignificant. The sloping arches and spandrel fillings which connect the columns of the tower on the four faces beneath the first story are singularly well adapted to the gigantic scale of the work.

Very careful observations were made from time to time as the erection of the tower advanced to check its verticality. These observations showed conclusively that the foundations had not yielded at all under their very moderate load, and that if any deviation from the vertical existed, it was so slight as to be scarcely appreciable with the most careful measurement. All the other calculations of M. Eiffel have been so complete and accurate, and his experience with high structures so exceptional, that his assurance may be taken with confidence that the oscillations of the tower at the summit under the most unfavorable conditions of wind pressure will not exceed 6 inches, while the periods of vibration will be relatively slow. Under ordinary conditions of weather the tower will remain absolutely rigid.

The success of the many problems attending the erection of the tower has been complete, and does M. Eiffel much honor.

The remarkable regularity with which this erection has been accomplished, and the fact that no correction of any kind was ever required, is an ample proof of the precision with which the innumerable parts that compose the structure were turned out from the ateliers of Levallois-Perret. This achievement also shows how well the arrangements for the erection were combined, all having come to pass as had been foreseen, without error, without accident, and without delay.

To obtain such a result, M. Eiffel has been admirably seconded by MM. Nouguier and Koechlin. M. Nouguier, who is chief engineer to the Eiffel firm, had the entire management of the erection of the famous bridge over the Douro (Portugal). He and his colleague, M. Koechlin, are well known for their entire competence in matters regarding iron structures, and have for twelve years taken an active part in all the works achieved by M. Eiffel.

COPYRIGHT IN PHOTOGRAPHS.

IN our SUPPLEMENT, No. 694, we gave an essay on the Law and Photography. The following addition is from the *British Journal of Photography.*

The latest exposition of the law of copyright in photographs is contained in the case of Pollard *vs.* Photographic Company, which is reported in the current (March) number of the Law Reports. The case is of considerable importance to portrait photographers, whether professional or amateur, the essential facts being these: The Photographic Company carry on business at Rochester, whither Mrs. Pollard went one day to have likenesses of herself taken from negatives made by assistants of the company. Apparently when she sat for her likeness no special terms or conditions were mentioned between herself and the photograper, the transaction being one of the ordinary kind, thousands of which take place every day. Mrs. Pollard, who is presumably a lady of considerable attractions, subsequently found her physiognomy figuring upon and embellishing a Christmas card, with the superscription in leafy letters, "A merry Christmas and a happy New Year," and a copy of this card was exposed for sale in the shop window of the company. Mrs. Pollard thereupon brought this action in the Chancery Division of the High Court to restrain the defendant company from selling or publicly exhibiting copies of her likeness, and has succeeded in obtaining a perpetual injunction against the company, who also had to pay the costs of the action. The judgment seems to be in accordance with common sense and natural justice, but the real interest to photographers lies in the arguments used by the counsel on either side and in the remarks of the learned judge before whom the case was argued.

Mrs. Pollard, as is usual with most sitters, had not registered any copyright in her photographs, so that the judgment in her favor depends in nowise on the copyright acts, the case being decided simply on the common law rights of contract and property.

From the official report, which virtually now swells the law on the subject, it may be gathered that a photographer who has been employed by a customer to take a portrait is not justified in printing copies of such photograph for his own use, and selling and disposing of them or publicly exhibiting them by way of advertisement or otherwise, unless the customer has given him an "implied" or "express" authority to do so. Now, the contract "implied" by law (there was no "express" contract) which was entered into between the parties when Mrs. Pollard sat to the photographer on this occasion was that he contracted not to use the negatives for any other purpose save for supplying her with copies. There is, therefore, a difference between a sitter who pays the operator for the photographs and the case where a snap shot results in a likeness secured. In this latter instance there is no contract implied or expressed to take the likeness; there is no consideration for the work and labor done; there is no money payment made to the photographer, and, therefore, it may be presumed that if the portrait does not transgress the rules and regulations of the laws pertaining to libel, if it be not calculated to expose the person, for instance, to contempt or ridicule, the photographer may sell it or exhibit it. As one of the counsel argued for the defendant company in this case:

"A person has no property in his own features; short of doing what is libelous or otherwise illegal, there is no restriction on the photographer using his negative." From this it would appear to follow that where an amateur photographer gets a person to sit to him, the artist has a right to exhibit the portrait because there is no contract that copies are only to be supplied to the sitter; there may even be no contract to supply him with copies at all, and, further, there is no consideration, no *quid pro quo.* The sitter sits to please the artist, the artist takes with the full intention of exhibiting the result if it proves satisfactory. That the amateur photographer intends to make some such use of the negative would be in the contemplation of both parties at the interview, though not actually mentioned. This is different from the case of Mrs. Pollard, where Mr. Justice North says: "The phrase, 'a gross breach of faith,' used by Lord Justice Lindley in that case" (Tuck & Sons *vs.* Priester), "applies with equal force to the present, when a lady's feelings are shocked by finding that the photographer she has employed to take her likeness for her own use is publicly exhibiting and selling copies thereof."

It was argued for the Photographic Company that inasmuch as the property in the glass negatives was in them, they were only using their own property for a lawful purpose. In reply to which the learned judge observed, "But it is not a lawful purpose to employ it either in breach of faith or in breach of contract." This is the pith of the whole case—contract, breach of contract. Similarly there is a well-known case as old as 1758 (Duke of Queensberry *vs.* Shebbeare), where the defendant was restrained by injunction from publishing a work, although a person had been expressly allowed by the owner to make and retain as his own a copy of the MS., which copy he had sold to the defendant; an agreement that the MS. was not to be published was here implied. So also a student may not publish a lecture which he hears and takes down in shorthand; and the receiver of a letter may not publish it without the writer's consent, although he might argue, like the photographer with respect to his glass and chemicals, that the property in the paper and ink is in him.

Though, as has been said, this case did not go off upon any law of copyright, still, as a matter of fact, the copyright in a photograph, where the sitter sits to the photographer in the usual way of business, is in the possession of the person whose features are portrayed. There is an act (25 and 26 Victoria, c. 68, s. 1) which provides that when the negative of any photograph shall be made or executed for or on behalf of any other person for a good or a valuable consideration, the photographer shall not retain the copyright thereof, unless it be expressly reserved to him by agreement *in writing* signed by the person for or on whose behalf the negative is made; the copyright in the photograph shall belong to the sitter. Therefore, if a photographer wishes to make any other use of a sitter's photograph other than supplying copies to the sitter's order, he should get the sitter to sign a *written* agreement that the copyright is thereby given to the photographer, who should pay something, even though a very small coin, for the same, and this sum should be mentioned in the agreement as the consideration.

But though the sitter paying for his photograph has thus a right to the copyright in his own features, by statute law he can bring no action against any one for infringement of his copyright, *until* he has registered the same in the usual way at Stationers' Hall.

J. HARRIS STONE, Barrister at Law.

CURING VANILLA.

THE process of curing vanilla in Mexico, a writer in the San Francisco *Chronicle* says, is a delicate one, requiring, as it does, not merely drying, but that the pods shall retain certain softness, that they shall lose little in weight, that they shall develop all possible fragrance, and that the active principle shall be brought out to coat the surface in the form of crystals, producing the effect familiarly known as "the silvering of the vanilla." For these purposes, the pods are spread in layers upon gratings of sticks or twigs, arranged in tiers for convenience of inspection.

These gratings are arranged in an ample room, dry and well ventilated. After twenty-four hours, the pods are picked over, and the green and the damaged rejected. If any show signs of opening, they are gently rubbed between the fingers wet in castor oil. The following day the pods are placed in the sun, spread upon dark colored blankets. Before sunset, they must be collected and stowed in a box or case wrapped in a blanket previously well sunned to expel possible dampness, and the pods carefully arranged in layers to preserve them in good shape. If this manipulation be properly conducted, the vanilla takes on, in sixteen or twenty hours, a very dark brown color. It is again placed in the sun, if the weather be fine; it not, spread on the gratings.

This process is followed for from twenty to thirty days, which is the time necessary for crystallization to take place, and during which it is sweated three or four times. If the weather be bad during the first important days of curing, or if the crop be very large, ovens are employed for drying, with a temperature ranging from 95° to 120°. For ovening, five hundred or six hundred capsules of vanilla are wrapped in a blanket, then in a petate or rush mat, and securely corded. The vanilla is left in the oven eighteen or twenty hours, as determined by inspection. The ovening must be followed by twenty or thirty days of sunning and sweating, as in sun curing. These processes over, the vanilla is assorted by grades, tied up in bundles of fifty pods each, and packed for shipping in tin cans or cases not dissimilar to coal oil cans, and, I shrewdly suspect, evolved from that article.—*Amer. Druggist.*

MEDICAL PRACTICE IN PARIS.

DR. CICARD lately appeared before the Seine Correctional Tribunal on the charge of illegally practicing medicine. The evidence showed he had a large and lucrative practice, and employed strange remedies. One witness, for instance, testified that the doctor wrote cabalistic signs on his prescriptions; another, that he had been ordered by him to hold a copper rod with both hands until it fell off; and still another, that he had been advised to stand on one leg. On being asked what he had to say, defendant replied he had an excellent defense in the shape of a simple document, which he would show to the court on condition the secret be kept. The judge having declined to make any such promise, after much hesitation the poor fellow reluctantly handed to the court a folded parchment, remarking he took this step only to avoid being sent to prison.

The document staggered the judge, as it proved Dr. Cicard's medical diploma, in good and due form. Of course defendant had to be acquitted; but on being asked why he had allowed himself to be prosecuted and risked going to jail, he replied that for five years after obtaining his diploma he had vainly tried to make a living by regular practice. Then, to avoid starvation, he hit upon the quackery dodge, and made considerable money. But now, that he had been obliged to show his diploma, the trick would work no longer, and he would be obliged to move to some other locality, where he would not be known as a regular physician.

ELECTRIC STREET RAILWAYS.

CAPTAIN EUGENE GRIFFIN, general manager of the street railway department of the Thomson-Houston Company, lately read a paper on "Electric Street Railways" before the Society of Arts, in Boston. President Francis A. Walker, of the Institute of Technology, presided, and there were present a large number of prominent electrical people. Captain Griffin first showed the necessity for electric roads by carefully prepared statistics on the passenger traffic in Boston and New York, and after a few words of introduction, illustrated by blackboard drawings, roughly showing the course of the current in the overhead wire system, proceeded substantially as follows:

The dynamo or generator and the motor are theoretically the same. If a steam engine be belted to an armature pulley and the armature pulley be made to revolve, a current of electricity is passed through the machine, the armature is made to revolve, and by belting to the armature pulley, mechanical power is available. In this way one dynamo will convert the mechanical power of the steam engine into electrical power, and the electrical power may be carried through the wires to the second dynamo, perhaps five miles away, where it is reconverted into mechanical power, and so made available for any desired purpose. The second dynamo is called the motor, and differs from the first, not in principle, but only in details which make it better suited for its special work. In this way we do away with the zinc fuel and come back to coal, except in those places where we are fortunate enough to have water power.

A brief description of the dynamo or generator and the motor is essential to a proper understanding of this subject.

The modern dynamo electric machine is simply an application on a larger scale of Professor Faraday's discovery that if a wire be moved through the magnetic field of a permanent electro magnet, a current of electricity is produced in that wire. A dynamo machine consists of a pair of field magnets, between whose poles or extremities revolves a soft iron rotating support, wound about with a series of coils of wire, in which the current is developed. The revolving body is called the armature. It is generally made to revolve by belting a steam engine to a pulley on the armature shaft. As each wire moves through the magnetic field of one pole of the magnet, the induced or generated current in the wire is in one direction; as the wire moves through the field of the other magnet pole, the current is in the opposite direction. The current taken from the poles of the machine or generator, as it is usually called, would therefore be alternating, were it not for the device called a commutator.

This consists of a copper cylinder on the armature shaft, divided into as many segments as there are separate coils of wire in the armature, each segment insulated electrically from the others and connected with its own armature coil. This commutator revolves with the armature, and against it are pressed two copper brushes, as they are called, which do not revolve.

These brushes are the current collectors, and when they are connected by a metallic wire five inches or ten miles long, so as to close the circuit, a direct current flows through this wire as long as the armature is made to revolve. Without going into details, it is sufficient to say that the brushes are so placed that as each segment of the commutator comes in contact with the brush, the induced current in the corresponding wire is flowing in a constant direction, so we have a direct instead of an alternating current. As a matter of fact the armature is not made up of separate coils; but the connections are so made with the commutator segments that we may theoretically regard the coils as separate.

The motor is practically the same as the generator, except that the power applied is electrical energy and the power obtained is mechanical. The current coming from the generator goes to the brushes on the motor, thence to a segment of the commutator and so to the armature coils. The wire with a current flowing through it in a given direction is repelled by one pole and attracted by the other. The powers of attraction and repulsion compel the armature to move, it revolves, and we have mechanical energy. We gear the armature to the car axle and we have motion.

There are two general methods of using electricity for the propulsion of street cars:

1. The direct method by conductors extending from the dynamo along the track.

2. The indirect method, by the use of storage batteries, secondary batteries, or accumulators.

In the direct method the conductors may be overhead, underground, or on the surface.

In the conduit system the conductors are placed in a conduit between the rails or between the tracks. The wires must be bare and yet must be thoroughly insulated from the ground—a condition very difficult to obtain under such circumstances. A slot about five-eighths of an inch wide gives access to the conductors by means of a contact plow, but unfortunately also permits the flow of water, slush, mud, etc., into the conduit. The present state of the art in this respect is illustrated by the conduit on Boylston street in front of this building.

The overhead wire is suspended from poles by brackets or from cross wires which span the street between poles on either side. When the street is of sufficient width, poles are placed in the center of the street between the two tracks, with bracket arms carrying the conducting wires. These poles are placed about 125 feet apart, and from actual experience are found to present little or no obstruction to traffic. The wires may be single or double. When single wire is used, the rails are utilized for the return current. When two wires are used, one wire carries the outgoing and one the return current. Contact is obtained with the wire by an over-running or an under-running trolley. The over-running trolley is a light carriage with one or more wheels resting on the wire.

A flexible conductor carries the current down to the car. The trolley is pulled along by the flexible conductor. The objections to the over-running trolley are that it is difficult to keep the trolley on the wire, it is difficult to replace the trolley when it comes off, and any automatic system of switching on to a turnout, branch, or Y is impossible. The latter is such a serious objection that except in special cases the over-running trolley will never be used. In the under-running trolley a light arm of the requisite length is mounted on the top of the car, reaching up to the wire. A wheel on the end of the arm is pressed up against the wire by means of springs at the other end, and the current is carried from the wheel down through the arm itself if made of metal or through wires if the arm is made of wood. This arm is usually called the contact bar. The under-running trolley is automatic in its action at curves, turnouts, etc., and follows the direction of the car. It turns on a swivel through the entire circle and moves through an arc of 90° in a vertical direction.

In the storage system, a battery of about 120 cells is carried on the car and the motors are driven by the current from this battery. The advantages of this system are:

1. The cars can run on any track.

2. No wires, either overhead or underground, are required.

3. Each car is more independent than is the case in other systems.

The disadvantages are:

1. The extra weight of about two tons on each car. The power required to carry this dead weight in addition to that required to drive cars required by the other methods.

2. The lack of efficiency in the batteries. The highest efficiency claimed is 82 per cent. The actual practical efficiency is stated by many authorities as about 70 per cent.

3. Storage cars cannot be regularly operated on grades exceeding 5 per cent. or 6 per cent. The power required on grades makes too great a demand on the batteries.

4. The expense. The cost of two sets of batteries per car is about $3,000.

5. The cost of maintenance. Batteries have not yet been made of sufficient durability to be operated economically.

There are four qualities which the electric motor must be shown to possess before it will be generally adopted for street car work. These are efficiency, economy, durability, and reliability.

1. As to efficiency: The steam engine is not an efficient machine. If we can utilize 15 per cent. of the units of energy stored in the coal we are fortunate. In other words, we must expect a loss of 85 per cent. of the heat units in converting the other 15 per cent. into mechanical power.

The dynamo electric machine, on the other hand, possesses a high degree of efficiency. No good generator runs below 92 per cent. efficiency. The loss in the line depends upon the amount of copper used in proportion to the current to be carried. The size of the conductor is generally calculated for a loss of 10 per cent. The efficiency of the motor under favorable circumstances has been shown to be but little below the generator; in actual tests running as high as 91½ per cent.

In practice it would not probably be taken higher than 85 per cent. Starting then with 100 horse power in the steam engine, we lose 8 per cent. in the dynamo in converting the mechanical into electrical energy. The output of the generator is then 92 horse power. In the line we lose 10 per cent. and deliver 82·8 horse power to the motor. Here we lose 15 per cent., and on the final reconversion into mechanical energy on the car we have 70·4 horse power out of the original 100 horse power. By no other known method could this power be transported to such a distance with so little loss.

2. Economy: This is perhaps a quality which appeals more directly to the railway official than any other. What will it cost? An electric railway connects Omaha with Council Bluffs across the new bridge. I am credibly informed that to run 20 cars per day they consume five tons of slack, for which they pay $1.14 per ton. This is 28½ cents per day for fuel. These cars are scheduled at 15 miles per hour, and the average daily mileage per car is over 100 miles. Where natural gas or water is available, fuel may be even cheaper. On many different roads from numerous measurements it has been found that where the grades are slight the power required averages from five to eight horse power per car. The consumption of fuel varies from three to six pounds of coal per horse power, according to the style of engine and its more or less economical operation. Of course a road operating only one or two cars would show abnormal results in every way, and these averages are only true of roads operating a number of cars—10 or more. The wear and tear on the generating plant does not exceed three per cent. The depreciation on line work does not exceed or even equal 10 per cent. The depreciation on car equipment has been variously estimated at from 10 to 20 per cent.

On some roads, under very favorable conditions, the cost of renewals and repairs to electrical apparatus has been but little below one dollar per day per car in actual operation. On other roads, under very favorable conditions, the cost of maintenance has been less than 25 cents per day per car.

A mean of the reports obtained from 11 roads in actual operation under different conditions shows a daily cost of operation of less than $2.50 per car, not including drivers and conductors. Experience has shown that it is well within limits to put the saving of electric over horse power at 25 per cent. In some cases a saving of 50 per cent. has been shown. The secretary of the Des Moines Broad Gauge Railway Company, under date of January 3, 1889, writes as follows: "The receipts from four cars electrically are four times more than five cars by horses."

3. Durability: The Washington road has been in operation for over six months. They now have seven motor cars and seven tow cars. The latter are double deck cars, on which 160 fares have been collected on one trip. These cars are hauled around sharp curves and up a five per cent. grade by two 10 horse power motors. While the track was new it settled. A car left the track, and while it was being pried back one of the motors was injured mechanically. With this exception not a single armature or field has been burned, and the gears show but trifling signs of wear. The road has operated without any repair shop, and practically without any repairs up to the present time.

At Lynn, Mass., a single car has been in daily operation since November 19 of last year. It runs 93 miles per day, and the 1·7 miles of track contains 11 curves and numerous grades ranging up to a maximum of 12 per cent. The durability of the electrical apparatus under such unusual conditions has been remarkable.

4. Reliability: On the Lynn road, above referred to, the single car has made its daily trips with but very few departures from the schedule. On one occasion the car axle broke, due to a flaw in the metal. On another occasion the belt slipped from the engine at the power station. Since the middle of February not a scheduled trip has been lost from any cause whatever, nor has the car failed to run on time. No one can look at the daily record of this car under conditions which would prevent horse car work, and doubt the reliability of electrical apparatus. On the Cambridge line of the West End road the conditions are unusually bad. During the month ending April 19, the schedule called for 5,912 round car trips. Of these the electrical cars failed to make just four trips.

As the railway employes become more familiar with electrical apparatus and learn more of the details of handling the cars, accidents, mishaps, and lost trips will grow fewer and fewer; but the records above referred to suffice to prove the reliability of the electric motor.

Storage battery cars are in operation on one road in the United States—the Fourth Avenue line in New York City. Conduits have been built in several places. In San Jose, Cal., and in Denver, Col., they were complete failures. In Allegheny City, Pa., the conduit has operated with considerable success. In Boston it has not been a marked success. There are at the present time over 100 roads in operation or under contract where the overhead wire system is to be employed. From this we may infer that the storage battery and conduit are yet in an experimental stage, while the overhead wire is a pronounced and demonstrated success. What the future of storage batteries and conduits may be no one can tell, but we all hope that the difficulties encountered may be overcome, as the storage system is unquestionably the ideal system.

The objections usually urged against the overhead wires are:

1. They are dangerous, as they carry death-dealing currents.

2. They are eyesores.

3. The poles obstruct the street.

4. They are in the way in case of fires.

Now, the railway wire should not be confounded with other electric wires. Arc and incandescent wires, telegraph and telephone wires, have simply to carry the current from the point where it is generated to the point where it is to be used, and so far as this purpose is concerned they may be above ground or underground. The railway wire, on the other hand, must have current taken from it every differential of an inch from one end to the other. The wire must be bare that the trolley wheel may be in constant contact. To put this wire underground and to keep it properly insulated is a very different problem from burying the other wires. The railway wire cannot be considered in the same category with other electric wires. Now, as to danger. For railway work we use a constant potential generator, and the cars and motors are placed between the two conductors on the multiple arc system. One conductor, the overhead wire, runs out from one pole of the generator; the other conductor, the rail, runs out from the other pole of the generator. An electrical connection between these two conductors completes the circuit, and the current flows through the connecting material, whatever it may be. If it be the motors on a car, then the cars move; if it be a man, he receives a shock.

Each connecting material, be it car, man, wire, or whatsoever, receives a current of electricity which is absolutely and always determined by Ohm's law that the current is equal to the electro-motive force or pressure divided by the resistance. The electro-motive force is always 500 volts. With several cars in operation, the amperes of current in the overhead system near the generator may run as high as 180, but each car takes its own proportion according to its resistance. The average resistance of a man is 4,000 ohms. If he places himself in the circuit, he will receive a current which is measured in amperes by dividing 500 by 4,000, or, in other words, a 500 volt current can only drive ⅛ of an ampere through the average human body. It would not make a particle of difference to the man whether the overhead wire he touched was carrying a current of 1 ampere, or 180 amperes, or 180,000 amperes. The effect in his case would be the same; he would receive ⅛ of an ampere. Were this not true, then the whole multiple arc theory would be false, and electric railways, as at present operated, would be impossibilities. It would then make no difference as to danger whether one or a million cars were in operation on the line.

To make this matter plain to those unfamiliar with electrical terms, we may suppose the overhead wire to be a large pipe or main through which a pump (the generator) is forcing water; the rails, electrically connected, as another large pipe through which the water is to be forced back to the station. Suppose the diameter of these mains is 12 inches. If they are closed at the outer ends, we may fill the overhead main, but after that no water can flow until we connect the two pipes. Now we will put in a one inch pipe connecting the upper main with the lower main, say 1,000 feet from the pump or generator. A certain amount of water will flow through the connecting pipe, which amount depends upon its size—one inch—and upon the pressure of the water in the upper main. From the generator to the one inch connecting pipe the same amount of water flows in the upper main as flows down through the connection, no more and no less. Beyond the connecting pipe, no water is flowing in the upper main.

Now we will put in a second connecting pipe 1,000 feet beyond the first. For the first 1,000 feet we have twice as much water flowing as before. Half of it goes down through the first pipe. It is the same with every additional connecting pipe we put in until we reach the capacity of the upper main or the capacity of the generator to force water through it. By increasing the pressure, we know that we could force more water through the one inch connecting pipe, but so long as the pressure remains the same, the quantity flowing through the inch pipe will be the same, whether the upper main be 12 inches, 12 feet, or 1,000 feet in diameter.

The analogy to electric railway work is close. Electricity takes the place of the water and the connecting pipes are electric cars, or it may be some unfortunate man placed where he ought not to be. He is only an

inch pipe, however, and the pressure (500 volts) can only drive so much electricity through him.

The current for railway work has been fixed at 500 volts, as this is well within the safe limits. A shock from 500 volts is unpleasant, but not dangerous. No man, woman, or child has ever been killed or even seriously injured by a 500 volt current. The United States Senate had this question before them last summer. After a thorough investigation the District committee unanimously reported that a 500 volt current is not dangerous. If there was any real question of its being dangerous, we would use 400 volts or 300 volts. The objection to this, however, is that by reducing the voltage we must correspondingly increase the quantity in order to retain the same horse power, and an increase in quantity (amperes) means an increase in the size of the overhead wires, which is objectionable. The danger limit with the electric current is probably about 1,000 to 1,200 volts.

The poles cannot obstruct the street, as they are inside the curb. They are just as much of an obstruction to the sidewalk as lamp posts and awning posts are; no more and no less. If the sidewalks be narrow and permission can be obtained from the property owners, hooks or eyebolts may be placed on the buildings, the cross wires fastened to these, and the poles done away with entirely.

Every overhead wire is objectionable to the fire commissioners; the railway wire is less objectionable than any other, because there is but one wire and this wire is in the middle of the street, away from the buildings.

If the single overhead working conductor is insufficient to carry the current necessary to operate the cars, it must be re enforced by feeder wires. These feeder wires may be insulated and may be placed underground The overhead wire may be divided into sections of three, four, six, or 1,000 feet in length. At the ends of each section a cutout or switch may be placed on the pole like a fire alarm box, so that in case of fire the current may be cut out of the section or sections in the vicinity of the fire. The firemen would then have no difficulty in handling the wires, which in any event are easily cut by pliers with insulated handle. As ladders are usually raised parallel to the face of the building, rather than across the street, and as the cross wires are 125 feet apart, it would be a very rare thing that the railway wires would be found to interfere at all with the operations of the fire department. As Prof. Thomson pertinently remarked to the insurance representative: It will not be long before you will be taking power from these wires to put out your fires. It will not be long before we have electric motor fire engines.

Charles J. Van Depoele and Leo Daft were the pioneers in the modern electric railway work in this country.

The first roads were built in 1884-85. The new motive power was, however, viewed with suspicion, and progress was slow until the Richmond road was built by the Sprague Company in 1887-88. This road did much to popularize electric motors. The rapidity with which the horse is now going is shown by the growth of the railway business of the Thomson-Houston Electric Company, one of the several companies working in this field. In the spring of 1888 this company purchased the patents of the Van Depoele Electric Company, of Chicago. At that time there were some 14 roads operating under the Van Depoele electric system. The first Thomson-Houston car was started at Crescent Beach, Mass., July 4, 1888. On the 1st of April, 1889, in less than nine months, there were 18 roads with 104 motor cars in operation, and 33 roads with 210 motor cars under contract. The Americans are essentially a fast people. We live fast, and, unfortunately, we die fast. But as long as we do live, we go. Any time-saving device is gladly welcomed, and at once becomes popular. The limit of speed with horse cars is about eight miles per hour. With electricity the only limit is what we may fix as a safe speed. If horse cars are delayed, there is little or no chance of making up lost time. The reverse is true of electricity. With electricity we have rapid transit, and we can obtain it in a very simple and not too expensive way. Electric motor cars do not smoke or give off noxious gases or make disagreeable noises. It is not necessary to run them in the air or under the ground, though they would run well in either position. They are safe, clean, fast, and reliable. They do not keep the street in an unclean and unhealthy condition. They do not take up as much of the street as do horse cars, for they have no horses. They are brilliantly lighted at night.

All of these qualities appeal to the public, and the verdict everywhere is favorable to electricity. The United States Senate and House of Representatives in reporting on a proposed extension of the Washington road, said: "It is undoubtedly the best electric railway in the United States, and beyond comparison superior to any horse railway."

To obtain these advantages the public must aid the railways. The rails must be of sufficient weight and of such form as to best carry the increased weight and stand the increased speed. Some form of girder rail weighing not less than 45 pounds to the yard is best suited to this work. The rail must be so placed as to be easily kept clean, and for this purpose should be slightly elevated above the surface of the street.

On the part of the railway companies, while the first cost is great, they can look forward to reduced operating expenses, a greater car mileage per day, and a great increase of traffic. Electricity has undoubtedly come to stay.

At the close of the lecture the subject was thrown open to discussion, and many interesting points were brought out by the questions asked the lecturer, which were in every case clearly and unhesitatingly answered.

A UNIVERSAL DEAD BEAT GALVANOMETER.*

By M. D'ARSONVAL.

THE apparatus which I am about to describe has been specially devised for physiological researches. But, in consequence of its arrangement, it can also be used for various kinds of measurements, temperatures, electromotive forces, resistances, capacities, current strengths, ballistic measurements, etc.; in fact, for electrical measurement generally.

This galvanometer is a tangent instrument, of the Wiedemann description, but with numerous modifications, of which practice has successively shown the utility and convenience.

The instrument is dead beat or ballistic as desired; it can be transformed into a Nobili astatic instrument, into a simple Thomson or into a differential Thomson, by a simple change of the magnetic needle and its attachments. This great elasticity has the advantage of giving a single apparatus of great precision adaptable to all wants (all the pieces which compose it being interchangeable) and of a moderate price.

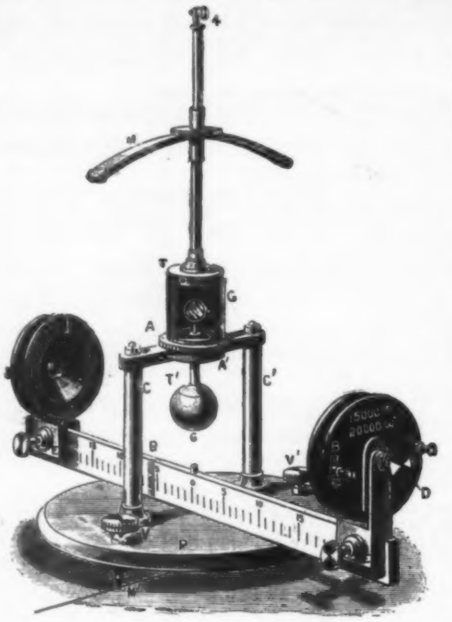


FIG. 1.

An important modification consists in the complete separation of the frame carrying the coils from the part which receives the needle attachments and the damper; the changes, the manipulation, and the carriage of the apparatus are effected with great facility. I will describe the two parts separately.

Fixed Part.—Fig. 1, which represents a perspective view of the galvanometer, and Fig. 2 a section of the movable part, are reproduced from *Revue Internationale de l'Electricite*. On a circular plate, P, a divided rule, R, can be clamped. The plate rests on three points, of which two only are adjustable screws, V, V'. The line which joins them is perpendicular to the direction of the rule, R, so that it is sufficient to place the screws, V, V', in the line of the magnetic meridian for the apparatus to be orientated once for all.

Along the rule can slide two carriers, E, E, provided with screws which enable them to be clamped. The upper parts of the carriers each carry a thumbscrew, D, which serves to fix circular coils, B, B', through which pass the currents to be measured. The frames of these coils are of wood and are each turned with a hemispherical cavity, in which the damping sphere, 6, fits. Each coil is provided with two terminals, and on the flat surface of the coils is engraved the number of turns and the resistance of the latter.

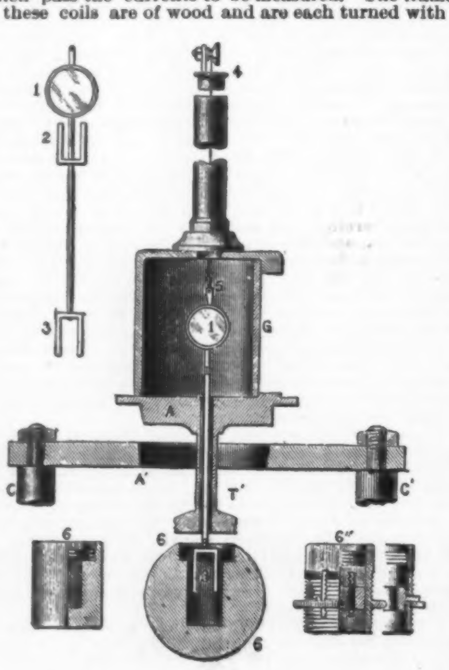


FIG. 2.

The renewal of these coils is an extremely easy matter, and costs very little. The coils are respectively of 150 turns of low resistance (0·4 ohm) and 15,000 turns of high resistance (20,000 ohms), for ballistic purposes and the measurement of electromotive forces.

On each side of the rule, R, two pillars, C, C', rise; these pillars are connected at their upper extremities by a cross piece, A', in which is a circular aperture, in which rests the portion, A, of the apparatus shown in detail in Fig. 2.

Movable Part.—The movable part (the magnet and its fitting and the damper) consists of a cylindrical box, T, of which the upper part is surmounted by a metallic tube, on the length of which slides the adjusting magnet, M (Fig. 1), and which terminates with a thumbscrew, 4, around which is wound the long cocoon fiber which suspends the magnet fitting.

The lower base, A, is chamfered, and fits closely into the aperture in the cross piece, A'. This base terminates by a small tube, T', at the end of which is a flare, into which screws the copper damper, 6. The box, T, has a square opening in its side, closed by a glass pane, G, which can be taken out when it is required to get at the mirror, 1, and its suspension, 5.

The glass, G, is set slightly oblique, as shown in Fig. 2, in order to avoid the reflections which are so annoying to the experimenter when the glass and the mirror are parallel.

The cocoon fiber, whose upper end is fixed to the adjusting screw, 4, is fixed at its other extremity to the mirror, 1, by the eyelet hole, 5. The simple magnetic attachment is formed of a little horseshoe magnet, weighing from 1·5 to 2·0 gr., and is in consequence of its shape very powerful; it can carry a weight 62 times as great as its own weight. It is screwed to a metal wire, to the upper part of which is fixed spring tight a piece carrying the mirror, 1; this allows the mirror being set in any convenient position. The piece carrying the mirror has fixed at its upper end the suspension eyelet, 5. The damper is formed of a copper sphere, 6, screwed to the flare at the end of T'. It has in it a cylindrical space in which the horseshoe magnet fits with about 1 mm. of space all round. As the sphere has a diameter of 4 cm., while the inside diameter of the horseshoe magnet is 1 cm. only, the damping is considerable, even without astaticizing the instrument; and, moreover, it remains the same in all azimuths. It can be seen that it is very easy to take off the damper without touching the magnet attachments. A simple sphere of thin brass can be used in the place of the one of solid copper, or a less powerful cylindrical damper, 6', or, again, an adjustable damper, 6''. The adjustable damper is formed of a ring of copper which can be slid in a split cylinder by means of two pins and an outside filleted ring, as shown by 6''. The magnet can thus be more or less inclosed by the damper, and thus the damping action be gradually altered. A liquid damper can be made by filling the thin sphere with any liquid desired. I prefer for the purpose ordinary paraffin oil.

By using the directing magnet, M, the instrument becomes one of the ordinary tangent type. If it is astaticized on the Hauy principle, the magnet, M, can be set at any required height in the ordinary way. The damping then becomes so considerable that one is obliged to diminish it by replacing the sphere, 6, by either the cylinder, 6', or the adjustable damper, 6''.

The instrument can also be astaticized by the Nobili method; to do this a second horseshoe magnet, 2, is placed in the stalk carrying the horseshoe magnet, 3, as shown at the upper left hand corner of Fig. 2, the poles of the two magnets opposing each other. As all the parts, 1, 2, 3, 4, 5, are separable, this is easily done.

Finally, the magnet attachment can be completely removed and replaced by a single or double Thomson arrangement, a liquid damper, if required, being used, which is very effective in this case. By withdrawing the eyelet of the mirror attachment, 1, and withdrawing the plug, 4 (at the top of the upper tube), it is extremely easy to change the cocoon fiber; the thumbscrew, to which the latter is attached, is of small dimensions, so that the adjusting magnet, M, can be withdrawn over it without touching the suspension.

By reason of the numerous applications to which the instrument lends itself, I have called it a "Universal dead beat galvanometer." The various modifications which practice has suggested, and shown the necessity of, have been carried out in the workshops of M. De Branville, 25 Rue de la Montagne-Sainte-Genevieve.—*Electrical Review.*

* This instrument was described more briefly and without illustrations in the *Review* for January 18, at the time it was presented to the French Physical Society.

THE PHONOPORE.

THE phonopore is a telegraphing device invented by Mr. Langdon-Davies, of London. Some two or three years ago, he first developed the system of transmitting signals through circuits which in the ordinary sense are not closed. Recent experiments in his laboratory were made through an artificial line of 4,000 ohms resistance, and comprised the sending of phonopore messages alone, and of phonopore and telegraph messages simultaneously, in the same wire, and in the same or opposite directions.

In one experiment the same wire transmitted a telegraph message and two phonopore messages simultaneously, and the working of the phonopores was perfect, even after the resistance of the line had been increased to 23,000 ohms, when the telegraph messages, which were received by needle instruments, could no more be read. A further experiment was made with a line wire open at both ends, and containing a resistance of 100,000 ohms. In this case the ordinary telegraph could, of course, not be worked at all, but duplex working of the phonopore was perfectly feasible.

At St. Pancras, messages were being sent by phonopore between London and Leicester in both directions, on one of the company's wires, which all the time transmitted ordinary telegraph messages. The London phonopore was joined to the line between two Morse relays about half a mile apart, one at the passenger and the other at the goods station, while the Leicester phonopore tapped the line thirty miles from the nearest telegraph instrument, which is at Derby. Between Leicester and London there are on this wire about six telegraph instruments, and as during operation the continuity of the line is constantly being broken by the working, each instrument is shunted by a phonopore, so that the phonopore messages are translated some six times.

We are informed that this method of bridging the telegraph instruments does not in any way diminish the clearness of signals as compared with a continuous wire. The messages were printed on a Morse receiver, which was actuated by a phonopore relay. The phonopore transmitter has a vibrating reed, and the distant phonopore receiver is also provided with a reed in the shape of a stretched steel band, which can be tuned to the same note. By choosing different notes

for each set of receiver and transmitter, the signals sent out from a station do not affect the receiver at the same station, but only that at the distant station, and the line can thus work duplex without any difficulty. One of the great advantages of Mr. Langdon-Davies' phonopore is that absolutely no alteration in the line and existing telegraph instruments is required, while its working capacity, by the addition of phonopores on either end, is doubled.

PHOTOGRAMMETRY.

ONE of the purposes to which it has often been proposed to apply the photographic image, but for which, up to the present, it has not been used to anything like the extent that was by some writers anticipated, is the serving as a basis for exact measurements, so as to be useful for the drawing up of plans and elevations of various natural objects, and to supersede or dispense, to some extent, with the work of the surveyor and engineer. True it is that in astronomical work the power of photography to render maps capable of exact measurement is fully recognized, and a design is on foot for a complete mapping out of the stellar universe by the aid of the camera, but in other directions comparatively little has been done. The modern developments of photography in the direction of the production of lenses giving images without distortion, and particularly the increase in the sensitiveness of the negative process, whereby we are enabled to use such small diaphragms in our lenses as to insure greater sharpness of the image—which, for this purpose, may be considered as equivalent to preciseness of position on the plate—have tended to remove or to ameliorate some of the difficulties which have stood in the way of earlier workers in this direction, and there is every probability of a more extensive use being made of photography as an automatic recorder of position, whose work may serve the purposes of the draughtsman for exact measurements, than at one time seemed practicable.

The interest now taken in photogrammetry, as the art of measuring and drawing by the aid of photography is called, is well evidenced by a paper on the subject recently submitted to the Photographic Society of Vienna by Herr Franz Hafferl, engineer, from a report of whose paper, published in the *Photographische Correspondenz*, we extract the following particulars.

Photogrammetry is described as deriving from photographs of objects their geometrical projection, elevation, and ground plan. Since a non-distorting lens will give a photographic image in true perspective, it is the task of photogrammetry to derive a geometrical projection from a perspective drawing. This latter problem was solved so far back as the year 1759 by the German mathematician Lambert. It was practically applied in the years 1791 to 1793 by the French engineer Beautemps Beaupre, who, while engaged in a scientific expedition, constructed a chart of a portion of the coast of Van Dieman's Land from drawings. It is evident that the result could not be exact, as it depended entirely upon the skill of the sketcher. It is only since the discovery of photography that it has been possible to obtain a picture in absolutely true perspective. The possibility of employing the photographic picture to the purposes of geometrical projection was remarked so long since as the year 1839 by Arago, and about the year 1842 Professor Laussedat, of the Polytechnic School, in Paris, practically applied the suggestion. Laussedat worked at first with the ordinary camera, then with the so-called panoramic camera, but finally with an improved "photographic plane table," made under his direction by Chevalier. All these apparatus exhibited many faults, so that at the present day they are no longer employed. Nevertheless, excellent results were attained by their means, and certainly the practicability of the method was placed beyond doubt by the labors of Laussedat and his co-workers.

The founder of the present system of photogrammetry is Meydenbauer, who, without a knowledge of what was being done in France, has worked at the subject since 1858, and has brought his method to such perfection that all others are laid aside when certain results have to be accomplished.

Meydenbauer worked with a metal camera having no adjustment for focusing, which, for the end in view, when using a lens of short focus and with small diaphragms, appears a quite permissible arrangement, considering the proportion between the distances of the object and of the picture from the lens and the size of the stop. The fixed distance of the lens from the sensitive surface insures great stability in the apparatus and constancy in dimensions, and simplifies the construction considerably.

The literature of photogrammetry is, unfortunately, very scanty, and is dispersed in various photographic and technical journals, in consequence of which an exact and complete description of Meydenbauer's apparatus could not be found. From what has been published, however, it appears that the apparatus now to be described, which was contrived by Herr Hafferl in conjunction with Herr Maurer, is identical in principle with that of Meydenbauer, but is different in economical and other considerations. In carrying out Herr Hafferl's ideas, he and Herr Maurer were assisted in the most friendly manner by the firm of Lechner, who placed their mechanical workshop at the disposal of the investigators.

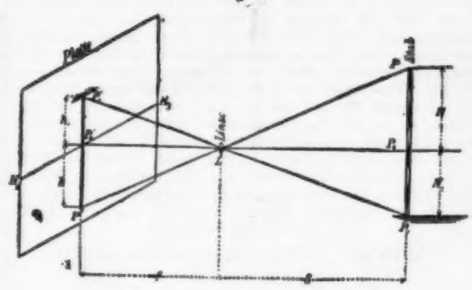
The metal camera, without adjustability for focusing, is fixed upon a theodolite head with cross levels, mounted upon a solid stand, such as is used for geodetic instruments. The lens, a Suter's aplanatic No. 3, is firmly screwed to the camera. As in all geodetic instruments, a contrivance in the nature of cross wires is adopted, which, in this case, however, is substituted by a single horizontal thread which lies in notches so arranged as to lie close to the plate during exposure, and leave thereon an indication of their presence.

In order to use the apparatus, it must be adjusted in three respects, that is to say: 1st. The pivot on which the camera turns must be vertical. 2d. The sensitive plate must be vertical. 3d. The horizontal thread—that is to say, the line which joins the two notches—must lie horizontally, and must intersect the optical axis of the lens.

This adjustment is effected with the aid of a leveling instrument, which is erected about the same height as the lens, close behind the apparatus. As soon as the requirements of the first of the necessary conditions is accomplished, in the same way as with all geodetical instruments, then, with the leveling instrument, we view its own reflected image on the back of the ground glass of the camera. When the ground glass stands truly vertical, the reflected image of the telescope must stand concentric with the circular field of the telescope. This adjustment is done with the assistance of a correcting screw.

Now, with aperture sights and with a leveling instrument, we note certain points in nature which are at the same height as the lens. The images of these points lie upon the ground glass on a horizontal line, which is intersected by the optical axis of the lens. These

Fig. 1.

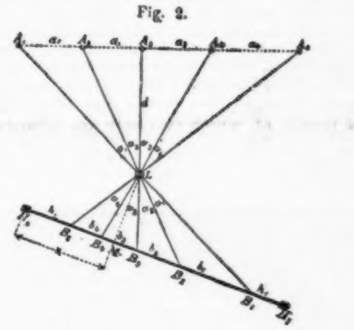


arrangements being made, we can bring the horizontal thread into exact position by means of correcting screws, and thus have fulfilled the third condition.

We can now produce pictures that will serve our purpose as soon as the apparatus is set horizontal by means of the cross levels. In order, however, to apply our picture to the construction of a drawing, we must know the point where the horizontal line cuts the line of the axis of the lens on the plane of the sensitive plate; and lastly, the length of the perpendicular or the actual distance of the picture from the optical center of the lens.

These two constant quantities are obtained by photographic methods. We place in the field, in a straight line, a number of ranging poles, marked A_1, A_2, A_3, A_4, A_5, in the accompanying figure. Perpendicularly opposite to A_3, the apparatus is set up at the point, L, and a negative is taken of these poles. On the ground itself we measure the distances of the poles equal to a_1, a_2, a_3, a_4, and the distance, A_3 L$=d$. In the picture, H_2,H_1 (which, in general, will not be parallel to the straight line, A_1,A_5), the images of the poles, A_1—A_5, lie at B_1, B_2, B_3, B_4, B_5, and we can measure the distances

Fig. 2.



of them, b_1,b_2,b_3,b_4, as well as the distances of these last images, B_1 and B_5, from the notches, H_1 and H_2, namely, h_1 and h_2. We have now to determine the distance of the point, M (the point where the perpendicular from the center of the lens falls upon the plate), from any one of the B's, and also the actual length of the perpendicular, L M$=f$. From the distances that have been measured on the ground, the angles, a_1, a_2, a_3, a_4, can be calculated, but these are equal to the similarly indicated angles in the camera. We now know, therefore, the position of the five points, B_1, B_2, B_3, B_4, B_5, and the measure of the angles between the ray from a sixth point, L, to these five points. For the determination of x and f, according to the so-called Pothenot's problem, three points and the angles corresponding to them suffice. We can thus calculate from several combinations of figures both dimensions; and thus we obtain a check, on the one hand, for the calculations, and, on the other hand, ascertain that the objective gives true delineation without distortion.

With our apparatus the position of H proved to be in the center between H_1 and H_2, the length, f, was

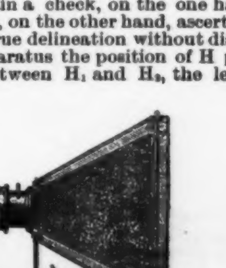


Fig. 3.

194·65 mm., and the determination was made after four photographs had been taken, and from each photograph two calculations were made.

The rectification as well as the establishing the constants may be attained in other ways, but the plan should be simplest that will serve for the particular apparatus.

From the pictures that have been taken we can now, as first mentioned, construct the ground plan and elevation of the objects included. As the simplest case, we will take the ground plan of the five ranging poles that have been photogrammetrically delineated. Having already taken the first photograph, we will take a second photograph from a second point, L', which point, however, must appear upon the first plate.

The only measurement required to be made direct from nature is that from L to L'. In order to construct the ground plan from the two plates, it is now necessary to place them upon the drawing as they lie in nature, that is to say, the plate taken from L must so lie behind the point, L, that its middle point, M, touches a circle described about L, with a radius of f, and that a straight line drawn through an image and the point, L, strikes the original object of that image; at the same time care must be taken that the direction to the right or left toward which the distance, M B, is drawn, is not reversed. So far as concerns an image and its object, each object, A, and its image, B, lie in one straight line with the center of the lens, L.—*Photographic News.*

THE HISTORY OF CLOCK MAKING IN OUR COUNTRY, AND THE LATE ELI TERRY'S CONNECTION WITH THE SAME.

IN a biographical sketch of a person whose name is associated with a particular art, it is requisite that the history and state of the art should be so far set forth that those conversant with it can clearly see in what way and to what extent the name of the person is connected with the art.

Among the early settlers in our country, there were clock and watch makers, as well as other artisans, and the manufacture of both brass and wood clocks was an early industry in various places in Connecticut, and the manufacture of watches at Ware, Massachusetts, was among the early industries in that State.

Eli Terry was born in South Windsor, Conn., April 13, 1772. He learned the art of clock and watch making and the art of engraving on metal of Daniel Burnap, in the city of Hartford; he also received instruction from Thomas Harland, a noted clock and watch maker, a resident of Norwich, and native of London. In the year 1793 he settled in Plymouth, Conn., engaged in the business of repairing clocks and watches, engraving on metal, and selling spectacles, spectacles being the only goods he kept for sale. In his early residence in Plymouth he did nothing at clock making worthy of mention, but in the year 1807 he obtained a contract from a clock maker in the neighboring town of Waterbury for making four thousand thirty-hour wood clocks with seconds pendulum, the dial and hands included, at four dollars apiece. At this date the manufacturers of clocks in this country made the eight-day English brass clocks and thirty-hour wood clocks, both kinds of clocks having pendulums beating seconds, or seconds pendulums, as they were called, with three exceptions. In that part of Plymouth now Thomaston there was a manufacturer of brass clocks, and also a manufacturer of brass clocks at Salem Bridge, now Naugatuck. These clocks were the English brass clocks with sixty teeth in the escapement wheel instead of thirty, to adapt them to a half seconds pendulum, the cord passing upward and over a pulley on the inside of the top of the case and attached to the weight, the weight moving the whole length of the inside of the case. These were the substantial differences. The plates for the frames of these clocks and the blanks for the wheels and other parts were cast metal, and the pinions were of cast steel, the same as in the English clocks. The length of cases required for half seconds clocks bears about the same ratio to the length of the cases for clocks with seconds pendulums that the lengths of the pendulums bear to each other. These clocks were popularly called "shelf clocks," and were thus distinguished from clocks with seconds pendulums, the cases of which stood on the floor. At Roxbury, near Boston, a timepiece was made called Willard's timepiece. This timepiece consisted of the time train of the English brass clock, with the omission of one leaf in the pinion on the escapement wheel arbor, the escapement wheel having an additional number of teeth, and was thus adapted to a pendulum shorter than the seconds and longer than the half seconds pendulums. This brass timepiece and the half seconds brass clock before mentioned were excellent timepieces. Such was the state of the clock makers' art in our country so far as relates to clocks for general use in the year 1807. To complete the contract mentioned, Mr. Terry was allowed three years. During the time he conceived the idea of making a thirty-hour wood clock with half seconds pendulum for general use, which would be much less expensive than the half seconds clock of cast brass. His first effort in this direction was an unsatisfactory success, the clock was substantially the movement of the thirty-hour wood clock with a seconds pendulum, the escapement wheel having sixty teeth instead of thirty to adapt it to a short half seconds pendulum. The cord passed upward and over a pulley on the inside of the top of the case and down around a pulley attached to the weight and back to the top of the case, where it was fastened. The front plate of the frame was an open plate, and the clock had no dial, but the figures to indicate the time were painted on the glass in the sash of the case. This clock did not suit Mr. Terry's aspirations, though he made and sold several hundred of them, and other manufacturers made and sold more than he did.

In the year 1814, he perfected a thirty-hour wood clock of a construction entirely new, both the time and striking trains having a greater number of wheels, and the clock being so radically different that it was really a new manufacture. Aside from the ingenuity as shown in the general construction of this clock, *there were two notable inventions;* the one consisted in arranging the dial works between the plates of the frame, instead of between the front plate and dial, and the other consisted in mounting the verge on a steel pin inserted in one end of a short arm, a screw passing through the other end and into the front plate. In wood clocks the pin was inserted in a button midway between the center and the periphery. By turning the button or arm, the verge was adjusted to the escapement wheel. In the manufacture of this newly constructed thirty-hour wood clock the numerous manufacturers of clocks at once engaged, and it became a very extensive industry, Mr. Terry making a very small fraction of the number made and sold. It super-

seded the half-second clock made of cast brass, and *that industry perished.* This clock supplied the American market and export demand for clocks for a quarter of a century.

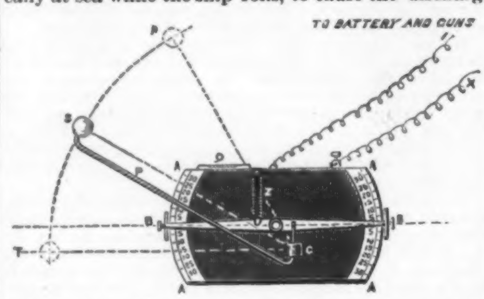
In the progress of the arts in our country sheet metal began to be manufactured, and rolled brass became an article of commerce. With a supply of this article in the market, sheet metal clocks began to be made. These sheet metal clocks with wire pinions were much less expensive than wood clocks, and superseded the manufacture of wood clocks as the manufacture of wood clocks had superseded the manufacture of clocks of cast brass. The two inventions before mentioned were adapted to brass clocks, as well as to wood clocks and to sheet metal clocks, as well as to clocks made of cast metal, and one or both are found in nearly every clock made in our country, and also in clocks made in other countries. It is worthy of mention at this point that all of the several kinds of clocks before mentioned were made to gauges, or so that the parts were interchangeable. The making of parts of a machine so that one part may be changed for a like part in another machine was an American invention. To whom the credit of the invention belongs we regret we are unable to state, but it was practiced in the clock maker's art as early as the year 1807. But Mr. Terry did not confine himself to making low-priced clocks for general use. He made brass clocks of fine quality, and sold them to watch makers for regulators, the price ranging from one to two hundred dollars, and also tower clocks. His tower clocks were novel, and consisted of three parts, a time part, a part to move the hands, and the striking part. By this construction the time part was not affected by the action of the wind and weather on the hands, the time part could also be placed in any part of the building desired, with a dial and handle attached and connected to the parts in the tower by a wire.

The tower clock which he made for the city of New Haven deserves special notice. The city at this time (1826) had no building suitable for a tower clock, and the clock was placed in Center Church on the "Green." This clock had the usual dial work, the hands connected with it showing *mean* time on a dial, and an extra train or dial works whereby the hands connected with it showed *apparent* time on an extra dial. This clock showing both mean and apparent time was not liked by the citizens, who were accustomed to apparent time, which was everywhere kept except in two or three of our principal cities, sun dials being common and every house having its own mark. The extra dial work, dial and hands for showing apparent time were removed, and the man in charge was instructed by Mr. Terry to set the clock to mean time, for he was determined that the clock should show mean time, and he still owned it and could do as he pleased, the city not having accepted it. In a tower on one of the buildings of Yale College there was a public clock "with an apparatus attached to it, which produced a daily variation from true time equal to the variation of the sun," causing the clock to show apparent time. These two public clocks not a block apart, one showing apparent time and the other mean time, occasioned a spirited controversy in the public press as to what was true time, or the proper time to be kept, in which there was a mixture of ridicule and learning. Those curious to read the controversy are referred to the files of the city papers of that day, to be found in the library of the institution mentioned. The communication signed "A Citizen of the United States" was written by Mr. Terry, and shows that he was master of the whole subject. At this day it seems strange that there should have been such a controversy, that learned men and others should have advocated the keeping of apparent time, and that in the year 1811, on a signal from the observatory of the college, a heavy gun on the public square was fired at noon to give the people the exact time to make their noon marks. Many residents of the city and graduates of the college in all parts of our country well remember these two old public clocks, which for many years chimed out their discordant notes. Some confusion has arisen from the failure of writers on the art to distinguish between clocks of cast brass and sheet metal clocks. The making of clocks of cast brass, the making of sheet metal clocks, and the making of wood clocks, so far as the mechanical part is concerned, are three distinct arts—are three distinct industries. Eli Terry died in Plymouth, in the post village of Terryville, called after his oldest son, Eli Terry, Jr., Feb. 24, 1852, falling short of the age of threescore and ten, one month and eighteen days.

J. T.

ROWE'S AUTOMATIC GUN-FIRING APPARATUS.

This apparatus is designed for firing guns automatically at sea while the ship rolls, to cause the discharge



to take place at the moment the ship is on an upright keel, thus insuring higher precision of firing and greater economy of ammunition. The board, A A A A, is fixed upright in any convenient part of the ship, and at the same angle with the hull as the guns the apparatus is to command. A spirit level, Q, is arranged with which to set the apparatus. S, P, and C are a globe, a pipe, and a cylinder; they contain mercury, which, pressing on the under side of the piston in the cylinder, C, actuates, by means of a connecting rod, the lever, B B, pivoted centrally on the board. The spring, Z, fixed to the board and lever, balances the action of the piston and connecting rod. The globe, pipe, and cylinder are fixed to the board, so that as the ship rolls they all move together, the globe rising to R or falling to T, or any other points, according to the amount of roll the ship has. This rise and fall of the globe varies the head of mercury and puts a variable pressure on the piston. This pressure is balanced by the spring, Z, suitably adjusted. The result is that the lever, B B, always remains in a horizontal position, while the board and globe move about it, partaking of the ship's motion. In the position shown the piston is at half stroke, the ship being upright. The lever, B B, is in an electric circuit, as also the board. It is so arranged that the electric contact is only made when the board, and, therefore, the ship, is upright, when the lever will be along the horizontal center line of the board. If at this moment everything is ready, the gun or guns lying in the electric circuit will be automatically fired, either by the current direct or by an apparatus actuated by it.—*The Engineer.*

TYPES OF THE FRENCH NAVY.

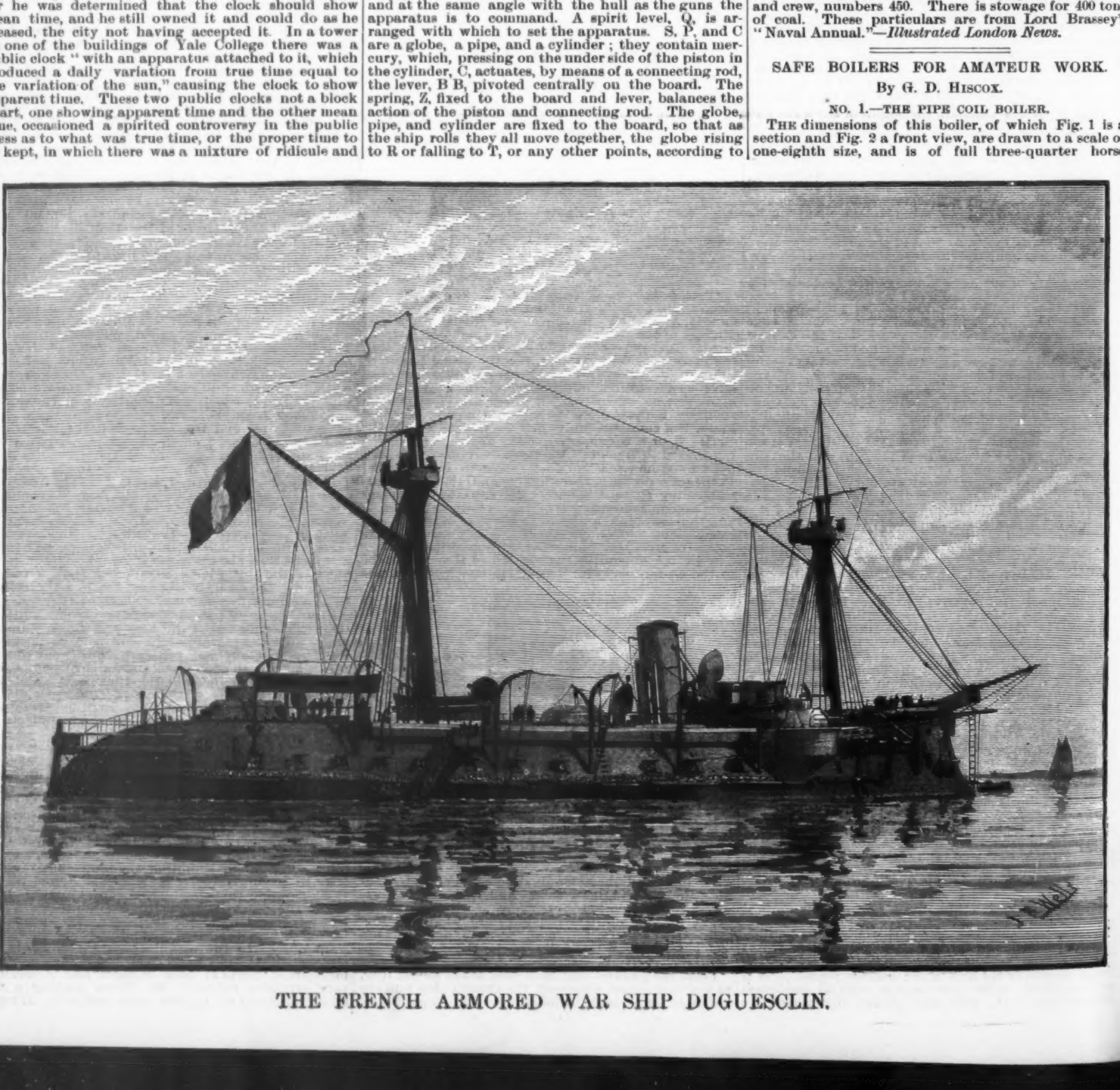
We have lately received from the publisher in Paris a small book on "La Marine Militaire," by M. Emile Weyl, in which the present condition of the French navy is compared with that of the German and the Italian, as well as the British; and the remarks of this author, being of later date than the report of the French commission, drawn up by M. Menard-Dorian, which is partly given in Lord Brassey's "Naval Annual" for 1887, are worthy of consideration. M. Weyl is far from being satisfied with the naval progress of France, any more than we Englishmen are satisfied with our own. But, instead of following him into the details of dockyard plans and construction, a subject which occupies so much attention in our own country, we will present an illustration of one of the new French ships actually built. The Duguesclin, named after the celebrated soldier who often fought against Edward the Black Prince in the fourteenth century, is an armored twin-screw cruiser launched at Rochefort in 1883, and finally equipped in 1886. She is constructed of iron and steel, and is sheathed with wood and coppered. Her displacement is 5,869 tons; her length, at the water line, 266 ft.; breadth of beam, 57 ft. The armament consists of four 9½ in. breech-loading guns, in four barbette towers; one 7½ in. breech-loading gun in the bow, and six 5½ in. breech-loaders in the broadside, with two 6-pounder quick-firing guns, and twelve machine guns. There are two above-water torpedo dischargers. The ship has a complete belt of armor, 9 in. to 6½ in. thick. The barbettes are forward, one abaft and one on each side amidships. They are covered with 8 in. compound armor. The conning tower on the fore bridge is of 2 in. plates. The Duguesclin's engines are of 4,100 horse power, and she has a speed of fourteen knots an hour. Her complement, officers and crew, numbers 450. There is stowage for 400 tons of coal. These particulars are from Lord Brassey's "Naval Annual."—*Illustrated London News.*

SAFE BOILERS FOR AMATEUR WORK.

By G. D. Hiscox.

NO. 1.—THE PIPE COIL BOILER.

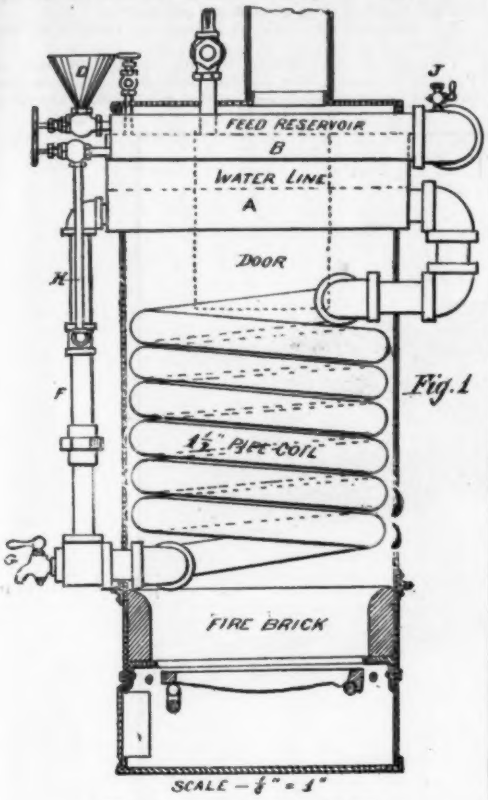
The dimensions of this boiler, of which Fig. 1 is a section and Fig. 2 a front view, are drawn to a scale of one-eighth size, and is of full three-quarter horse



THE FRENCH ARMORED WAR SHIP DUGUESCLIN.

power, having 13 square feet of fire surface. The coil should be made of $1\frac{1}{2}$ in. lap-welded pipe, $6\frac{1}{2}$ turns, and connected with the steam drum, A, above, with the same size pipe and fittings.

The steam drum is made of 5 in. pipe, 18 in.

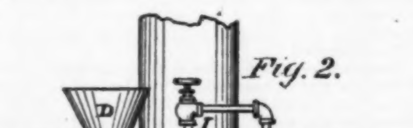


No. 1 PIPE COIL BOILER.

long, headed at each end by welding in a disk of iron one-half inch thick.

The feed water reservoir, B C, which also answers the purpose of a heater, is made of $2\frac{1}{2}$ in. pipe in two pieces, each 18 in. long, with welded heads at one end and connected together with two elbows and a cross pipe 5 in. long.

The return circulation, F, should be 1 in. pipe with a cross 1 in. by $\frac{3}{8}$ in., placed at a suitable place in the pipe, F, to accommodate the length of the water gauge glass, and to which the $\frac{3}{8}$ in. feed pipe, H, is also connected.



No. 1 PIPE COIL BOILER.

The circulation of the water in this boiler is perfect, with a provision at the bibb, G, for blowing out the entire contents when required.

The valve at B, on the feed pipe, H, is for regulating the feed and to close the feed water reservoir when it is required to be filled.

The valve, I, and $\frac{3}{8}$ in. pipe connection from the boiler to the feed water reservoir is for equalizing the pressure in the reservoir while feeding the boiler. When filling the reservoir, the valves, B and I, should be closed, and the valve at C and air cock, J, open, when the reservoir may be readily filled through the funnel, D. The safety valve is $\frac{3}{4}$ in., and the gauge cocks $\frac{1}{8}$ in.

The shell should be made of No. 12 sheet iron, in two sections, put together with hoops of small angle iron (1 in.), fastened with stove bolts. Four inches of the lower shell should be lined with fire brick or soapstone, resting on a hoop of angle iron upon the inside.

The back part of the grate is supported by a round bar of $\frac{3}{4}$ in. iron passing through holes in the shell for support. The front of the grate rests upon a double crank also passing through holes in the shell for support, with a square on its end and a lever for shaking or letting down the grate.

The upper section may, for convenience, be made in two halves and closed around the protruding pipes with lugs and stove bolts, the reservoir being pushed through the holes after the shell is put together.

The boiler, if put together with good cast iron fittings and steam metal valves, is perfectly safe for 150 pounds steam pressure, and may be tested to 300 pounds hydraulic pressure.

If there is any doubt as to the quality of the cast iron fittings, malleable iron fittings made purposely for steam may be obtained through the fittings trade.

The boiler, between the upper and middle gauge cocks and the reservoir, holds 12 pounds of water, sufficient to furnish steam for a 2 × 3 engine cylinder, making 150 revolutions per minute at 50 pounds pressure for over two hours, or one-third horse power without refilling, and for one hour at 100 pounds pressure indicating two-thirds of a horse power.

With a pump connecting with the valve at C and a steady feed, the engine may be run at full one horse power.

A smaller size boiler can be made on this model by making the coil of $1\frac{1}{4}$ in. pipe, and all other parts in proportion for a half horse power, or with 2 in. pipe for a one and a half horse power.

NO. 2.—PIPE BOILER.

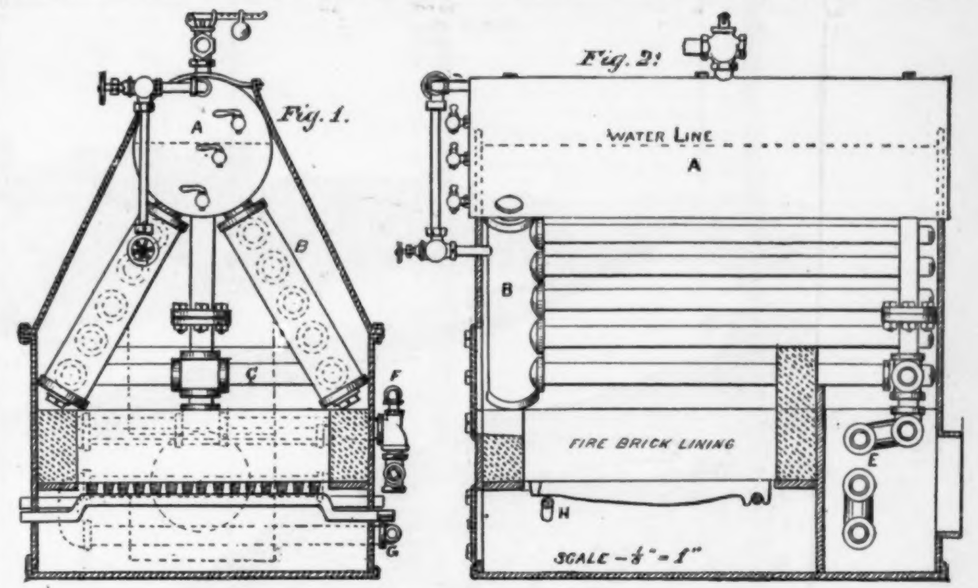
This boiler requires no bent coil, as in No. 1, nor the special services of a blacksmith, if the heads of the drum are extended far enough to have a cap screwed on each end instead of the welded heads. The outside covering frame and bearing plates are designed to be made of cast iron, for which the services of a patternmaker, or a carpenter, if the amateur can detail the plans of the pieces, may be needed.

In the hands of a good pipe fitter or worker in iron, the covering frame may be made entirely of wrought sheet iron, No. 12 wire gauge, with angle iron bearing and stiffening plates.

All the essential measurements may be taken from the drawing, which is to a scale of $\frac{1}{8}$ in. to 1 in.

The shell, A, should be made of a piece of 8 in. wrought iron pipe, cut $30\frac{1}{2}$ in. long if for welded heads, or 33 in. long with threaded ends if caps are used.

The five branch tees with 1 in. outlets, and $1\frac{1}{2}$ in. nipples at the upper ends, are set at an angle of 60° in the drawing, although a less angle will make a narrower setting without detriment to its steaming qualities. Eight of the horizontal pipes from the branch tees are closed at one end by welding, or caps may be used instead. The two bottom pipes should be cut with a left hand thread at the elbow ends of the cross pipe, C, and both made up at same time; being fitted so that the half union flange on the vertical pipe, D, will draw to its exact place.



No. 2 PIPE BOILER.

The feed water may enter at F, or a feed water coil may be put in as at E, and the feed water enter at G, which will add to the economy of the boiler by absorbing waste heat.

The offset front bearer bar, H, allows the grate to be dropped sufficiently for drawing the fire.

The gauge cocks may be $\frac{1}{4}$ in. cylinder cocks or air valves of the trade.

The water gauge of the smallest size in the trade and fitted up with $\frac{3}{8}$ pipe connection. Safety valve $\frac{3}{4}$ in.

For lining the fire chamber, extra long fire brick, $2\frac{1}{2} \times 4\frac{1}{2} \times 13$, should be used, with the ends cut and beveled so as to tie them in place.

The roof plates should be held close to the drum by strap bolts over the top, as shown in the drawings. All crevices between the outside covering plates should be filled with asbestos putty.

The drawing represents a boiler of one horse power, having 12 square ft. of effective fire surface, and may be somewhat increased by adding 10 or 12 drop tubes 1 in. along the under side of the drum.

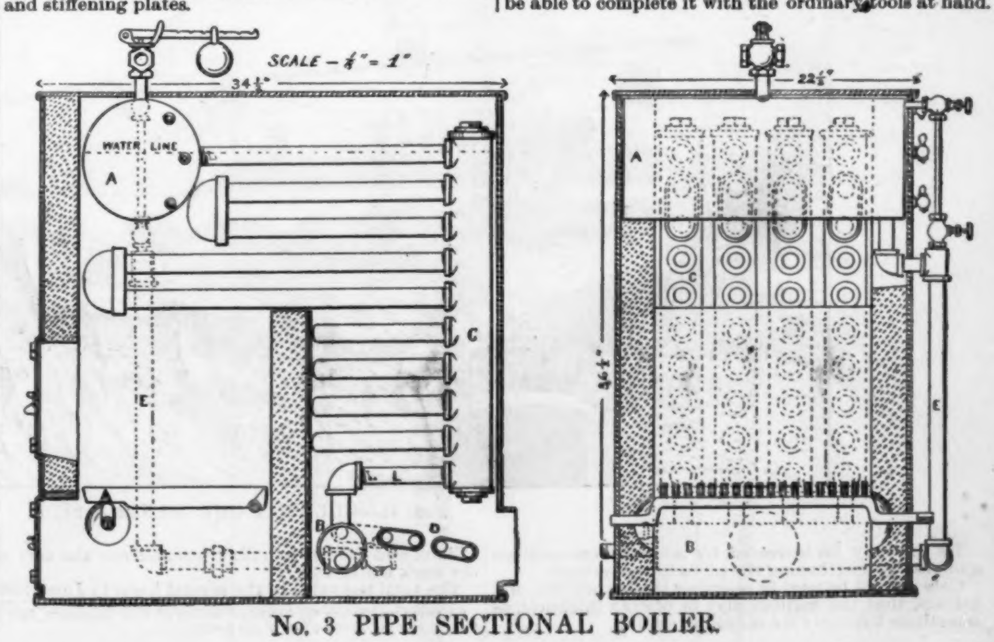
The arrangement of the tubes in this design admits of a free circulation of the water through the extreme circuit of the boiler, so that the steam issuing from the headed tubes is quickly carried into the drum. The water may be entirely drawn or blown out at the blow-off cock as shown, or if the feed water coil is used, the blow-off cock should be placed at the bottom.

An iron casing is not necessary to this form of boiler, for by extending the steam drum a few inches at the ends, it may be entirely inclosed in brick work.

This form of boiler may be tested to 250 lb. hydrostatic pressure per square inch, and good for 150 lb. steam pressure.

NO. 3.—PIPE SECTIONAL BOILER.

The pipe sectional boiler as here represented by sectional elevations made to a scale of $\frac{1}{8}$ in. to 1 in. is made wholly of materials used in the pipe fitting trade, and in such a way that an engineer or pipe fitter should be able to complete it with the ordinary tools at hand.



No. 3 PIPE SECTIONAL BOILER.

The only special work is the welding in of the heads of the 8 in. pipe for the steam drum, A, and the 3½ in. extra strong pipe for the mud drum, B. These, if desired, may be made long enough to admit of threads with caps screwed on, outside of the case or setting.

The steam drum should be tapped with left hand threads at L, for connecting the section, S; the lower connection, also marked L, should be at a right and left elbow. The return bend should have both outlets with left hand threads, to facilitate putting together in the same manner as in radiators.

The sectional pipes are 1 in. and the ten branch tee 1 in. by 2 in. run. The sections should be 4 in. center to center, and the branch tee and 1 in. pipes 2½ in. center to center. A feed water heater may be introduced at D, connected to the mud drum with a slight inclination, to allow any steam that may be generated in the coil to rise into the general circulation of the boiler. The outside casing may be made of cast iron plates, or of thick sheet iron, No. 10 or 12, and lined with fire brick or fire tiles 2½ in. thick. The eccentric front bearing bar allows the grate to be partially dropped for cleaning.

For a boiler of four sections, having a nominal 1½ horse power, as shown in the drawing, the safety valve should be ¾ in. Gauge cocks ¼ in., and ⅜ in. water gauge valves. The circulating pipe, E, should be 1 in.

This is a free circulating boiler having a large surface on the water line for steam delivery, and a full sized grate, so that a moderate fire of nut coal may be used with light draught.

Its size may be increased by adding more sections and also by lengthening the pipes in the sections.

Care should be used in selecting the branch tees and fittings, that the castings may be of even thickness, as sometimes the cores are sagged in setting.

This boiler should bear a test of 250 to 300 lb. pressure and be safe for 150 lb. steam working pressure.

[Continued from SUPPLEMENT, No. 701, page 11198.]

PLANT AND MATERIAL OF THE PANAMA CANAL.*

By WILLIAM PLUMB WILLIAMS, Jun. Am. Soc. C. E.

THE WORK DONE AND TO BE DONE.

IN connection with the paper on the "Plant and Machinery on the Panama Canal," it may be interesting to engineers to be informed how much work has been accomplished by the use of this plant on the canal, and how much work remains to be done, and the probable cost of that work.

The first estimate of the work to complete a sea level canal, stated at the "International Congress" at Paris in 1879, was a cube of 46,000,000 meters, which was increased later to 75,000,000 cubic meters and 105,000,000 cubic meters; while in 1885 this estimate was still further increased to 151,000,000 cubic meters, of which 20,000,000 cubic meters was for "derivations."

The official reports state that up to June, 1888, the Canal Company had expended $177,910,000, and had accomplished 49,000,000 cubic meters, showing an expenditure of $3.62 per meter. This work has been accomplished under conditions much more favorable than will be encountered in the future, when, as the cuts are deepened and the material becomes harder, the length of haul and time of handling will increase the cost of the work materially.

The total par value of the several loans to June, 1888, is $351,150,900, the loans having first been taken in 1882 at a discount of 12½ per cent., bearing interest at 5 per cent., while the last loan was floated at par, bearing 3 per cent. interest, and was finally taken up at 56 per cent. discount.

The interest and fixed charges on this amount expended is more than $20,000,000 per annum.

An accurate idea can be gained by looking at the profile on Fig. 18.

This profile was issued by the Canal Company in Paris in January, 1888, for the purpose of infusing new interest among financiers in the adoption of the lock system. The showing of the profile and the comparison between work to be done and work already accomplished was so dangerous to the Canal Company that the issue of this profile was suppressed.

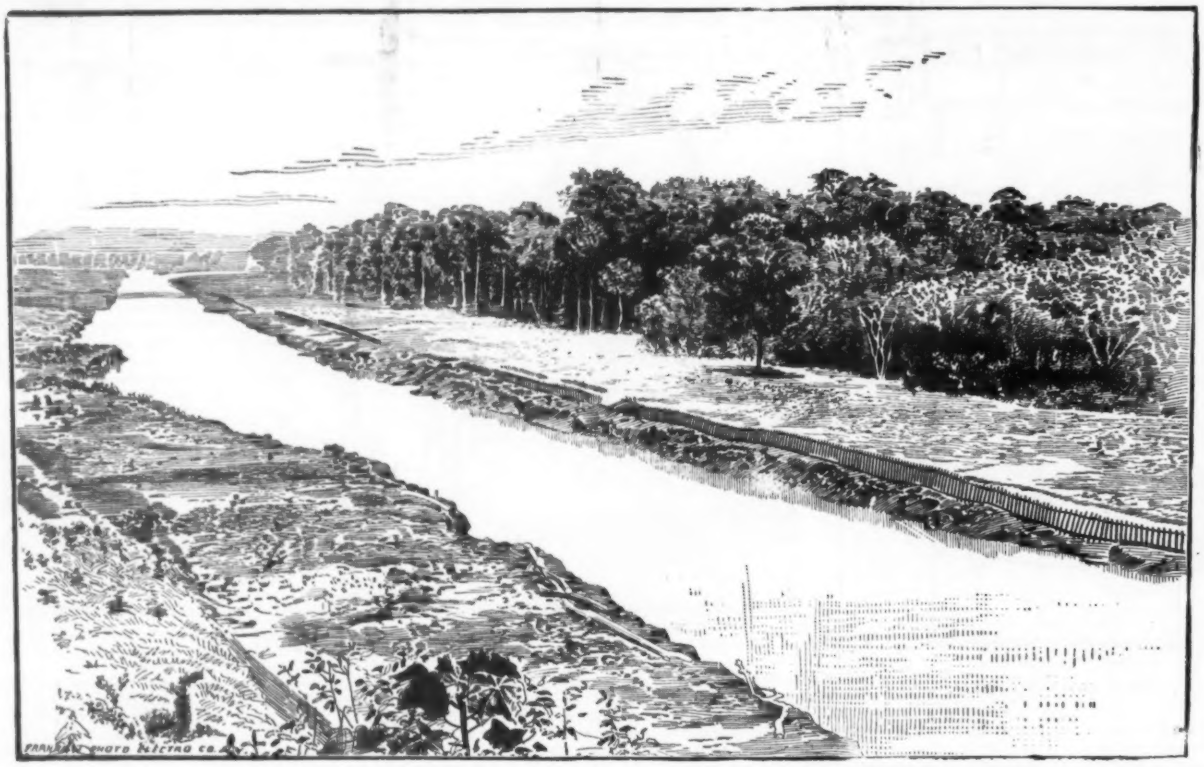


FIG. 19.—SECTION OF CANAL, COLON SIDE, EXCAVATED IN LOW GROUND BY AMERICAN "HERCULES" DREDGES

The first announcement made by the Canal Company that 40,000,000 cubic meters remained to be extracted under the lock system was still further reduced in the publication of May 2 in the *Bulletin du Canal Interoceanique*, that only 32,132,244 cubic meters remained to be extracted.

A careful calculation by scale as shown on the profile of the amount of excavation for the lock canal between kilometers 18 and 68 gives 37,250,627 cubic yards. These estimates are made by taking the center heights and slopes at 1½ to 1.

In a number of cases the center of the canal has been excavated deeper than the sides, so on this profile, which was taken along the center line, we do not get the average cutting, but a height much more favorable to the canal than against it. The slopes in many instances have been carried further back at an angle of 2 to 1 on account of the sliding tendency of the soil.

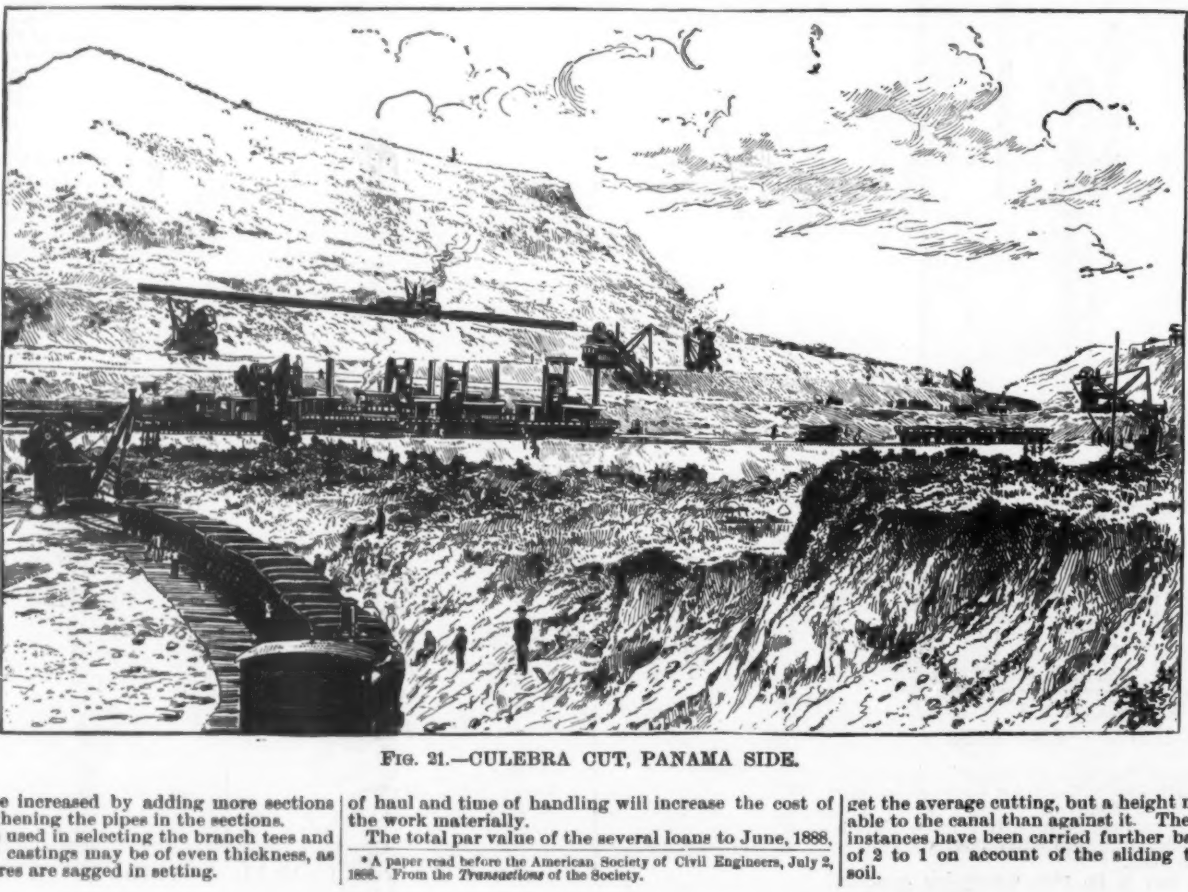
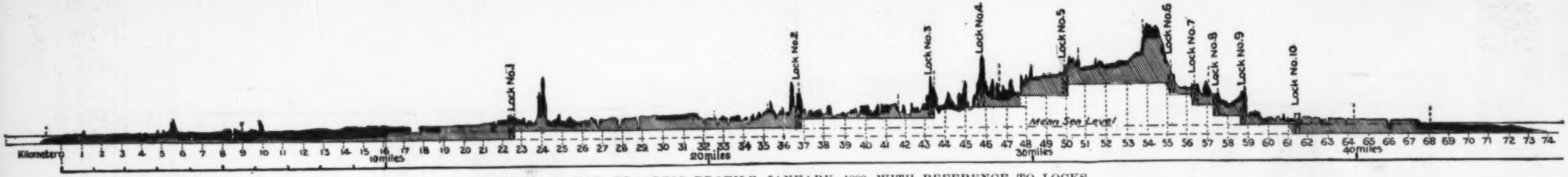
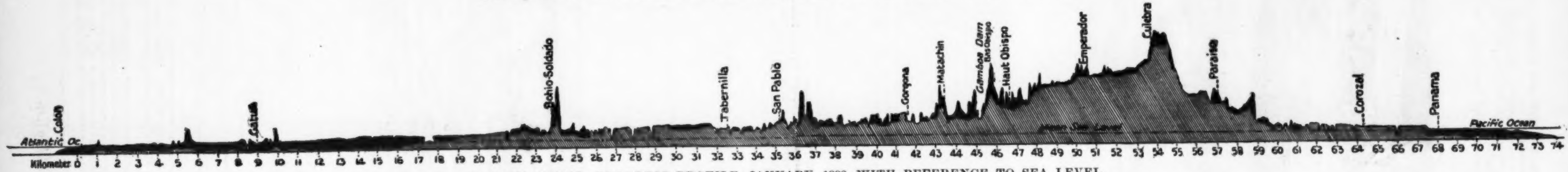


FIG. 21.—CULEBRA CUT, PANAMA SIDE.

* A paper read before the American Society of Civil Engineers, July 2, 1888. From the *Transactions* of the Society.



PANAMA CANAL—PROGRESS PROFILE, JANUARY, 1888, WITH REFERENCE TO LOCKS.



PANAMA CANAL—PROGRESS PROFILE, JANUARY, 1888, WITH REFERENCE TO SEA LEVEL.

Fig. 18.

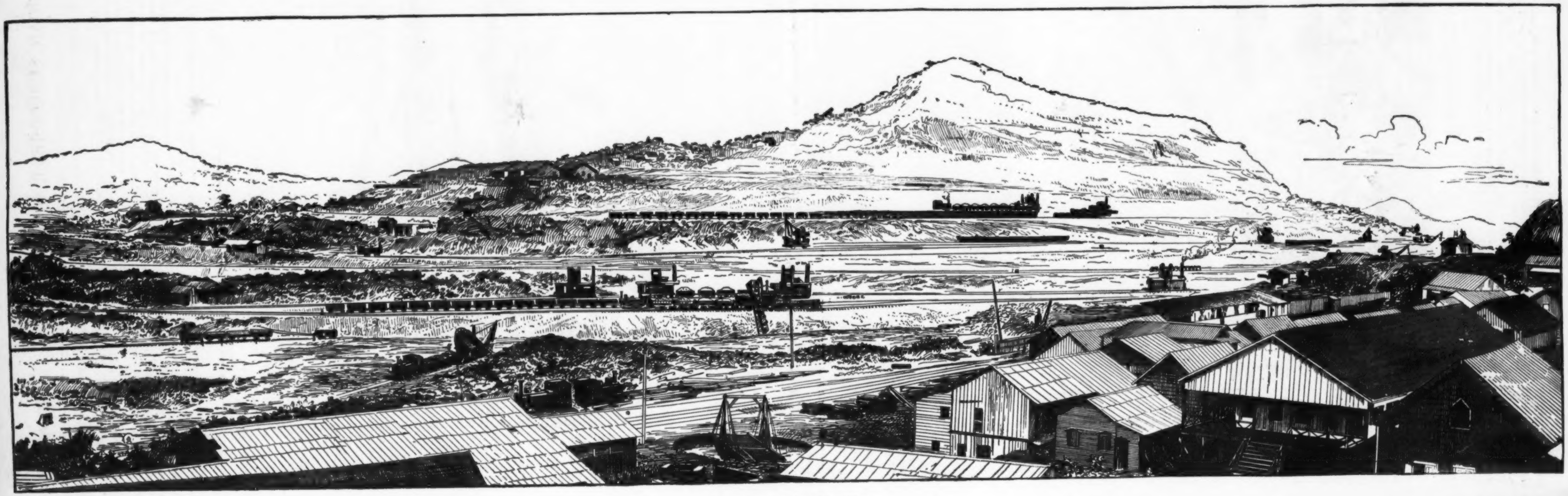


Fig. 20.—CULEBRA CUT.

This estimate does not include the amount of excavation necessary for the "derivation" on either side of the canal, as while the location of the canal itself is made with a view to the most advantageous operation, it is not always possible to find equally favorable locations for the parallel channels.

In places the amount of excavation in the derivation channel exceeds the cube of the canal. Again, this aggregate amount does not include the excavation in deepening the canal from 15 to 27 feet between kilometers 1 to 18, and the excavation from kilometer 68 to 74, which is of the most difficult nature, as coral rock has been met with all along this section.

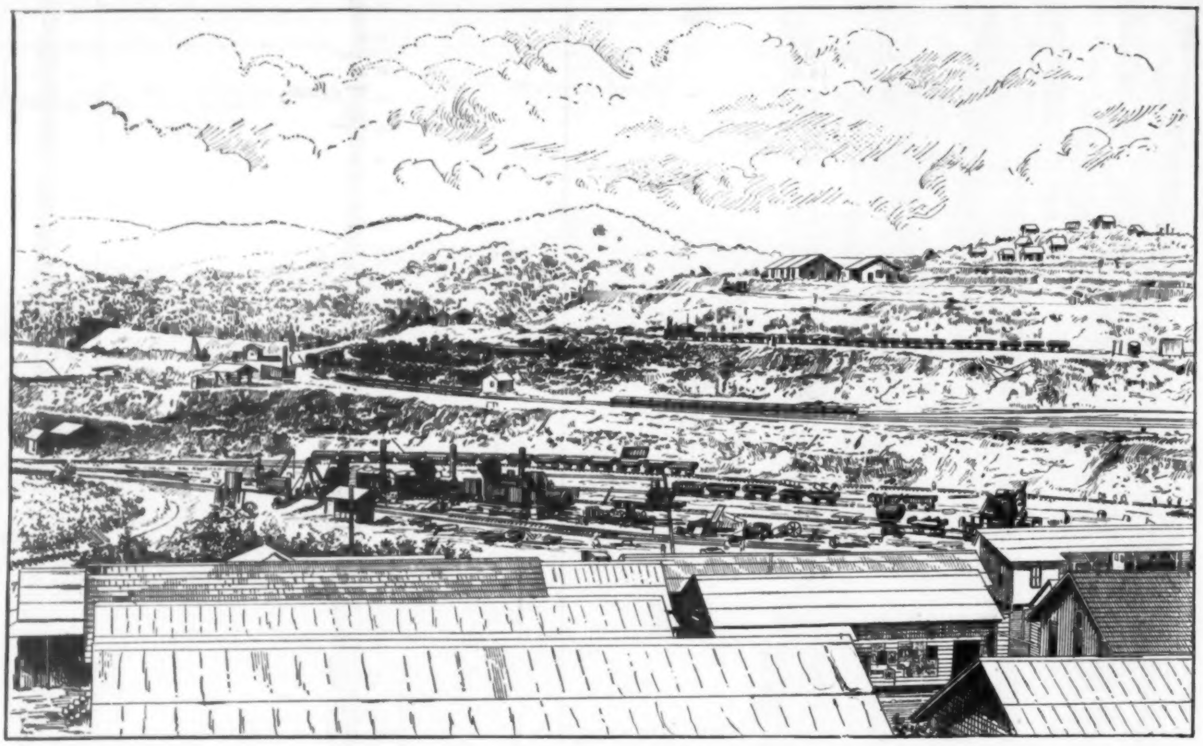


FIG. 22.—CULEBRA CUT, COLON SIDE.

It is safe to estimate that the excavation necessary to complete the lock canal and derivations will exceed 60,000,000 cubic meters, and the cost of handling $2.50 per cubic meter, requiring $150,000,000 in cash outlay.

The interest and fixed charges on work already accomplished for the next four years, the earliest possible time at which it might be completed, will be $80,000,000.

From past experience at least $2.50 for $1 will have to be paid for the negotiation of the new securities. This will necessitate obligations to be issued of $575,000,000, which, in addition to the $351,000,000 debt already incurred, would give a total of $926,000,000 as the cost of the completed canal.

The tonnage of the world availing itself of the use of the canal in 1892 will not be over 5,000,000 to 6,000,000, which, if taxed as high as $3 per ton, would only yield $18,000,000.

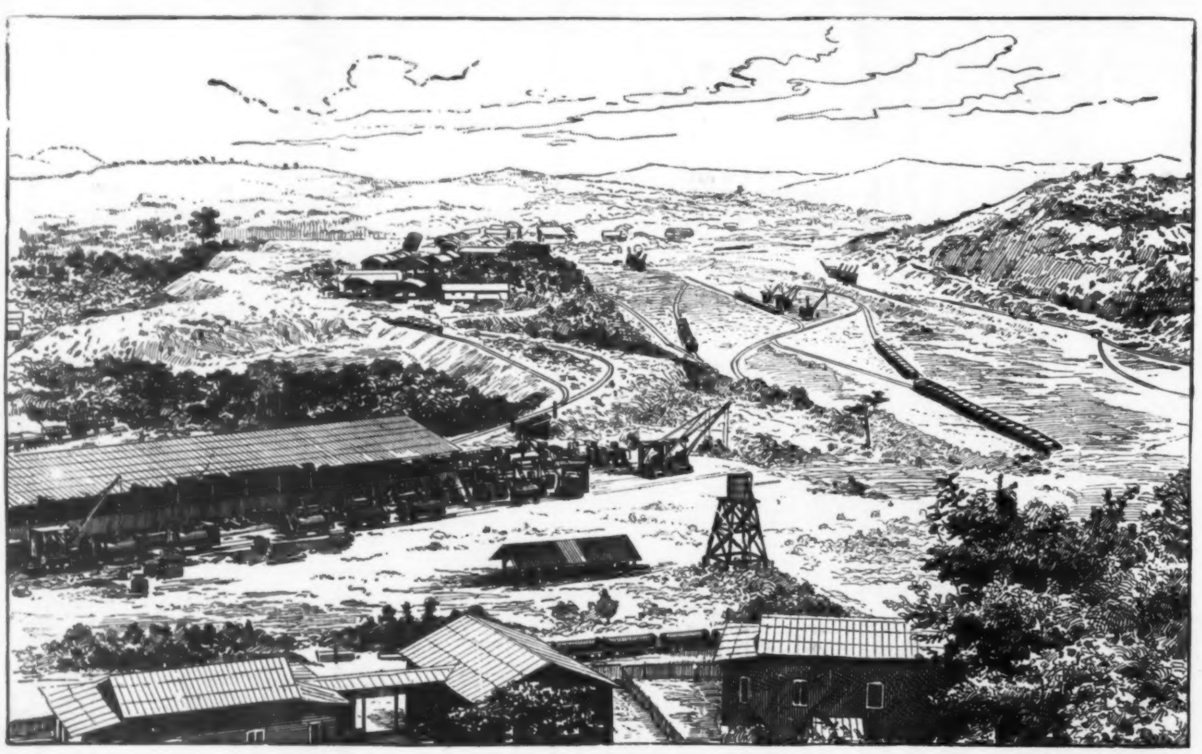


FIG. 23.—CUT AT EMPERADOR.

Then the cost of operating a lock canal with an artificial water supply will at least require the expenditure of $3,000,000 per year.

Even at this high rate of tax on tonnage, the canal would only yield a dividend of a little over two per cent. per year.

The future work and completion of the Panama project is purely theoretical, and problematical in the extreme, standing, as it does to-day, on the verge of a financial crisis, which may be hastened at any moment by De Lesseps' death, as no man has succeeded in raising such sums of money for an enterprise which at the start was so misjudged and underestimated.

At this late date problems relating to the Chagres River control are still unsolved, and the blunders of the past will surely creep in during future work.

Now, the company's rate of excavation, even with the help of the large figures from the Colon-Gatun section, has not averaged 1,000,000 cubic meters per month, the past two years through. At the best rate of progress, therefore, and with the most liberal allowances, there is work enough to consume four years, and that would involve the disbursement of something like $80,000,000 for interest and sinking fund of the debt and expenses of administration, without counting a dollar for work or material on the canal itself.

Though the work accomplished thus far has been the easiest that the line presents, still, more than one contractor has succumbed before the difficulties of the Culebra. Some of the richest and most experienced firms of Europe have declared the tasks of that portion of the line beyond their power to accomplish, and have abandoned their contracts. Those tasks have not been lightened nor the difficulties lessened by the operations hitherto effected. The laborers are not more numerous nor more efficient than they were when Senor Tanco Armero declared that the results of their work convinced him that there had never been more than 5,000 men employed, though the company claimed to have 15,000.

Again, the water for the supply of the lock system, so far as is known, is to be furnished from the Chagres River. In the dry season the flow of the Chagres is at the rate of 10 cubic meters per second, of the Obispo 1 cubic meter, and of the Rio Grande 0·4 cubic meter. The three streams would therefore supply some 259,977,600 gallons per day. The capacity of each of the locks is 40,000 cubic meters, and each vessel crossing the summit level will require the two locks to be emptied once, using something like 80,000 cubic meters of water. The Panama Company claims a tonnage of 10,000,000 per year, or 28,000 tons per day, representing twenty vessels of 1,400 tons each, although this seems to us a most exaggerated estimate. The water required for their transit would be 322,400,000 gallons per day. The evaporation and filtration, estimated at one per cent. per day, would entail a loss of something like 47,300,000 gallons, making the daily requirement amount to 369,700,000 gallons. The supply is 259,977,600, and the shortage on this basis 109,765,260 gallons.

In the rainy months the opposite conditions will prevail.

The Gamboa dam, as originally proposed by French engineers, was to be 975 feet long on the base and 113 feet high, with outside slopes of 4 to 1, and was to consist of 10,000,000 cubic meters of rock and clay. The site was to be dredged some 60 feet to a solid foundation. These plans have been changed on account of the adoption of the lock system, and the dam will only be carried to a height of 95 feet. Its total contents are 3,000,000 cubic meters, and already about 30,000 cubic meters have been deposited on the flanks of the hills at the two ends. No excavation has been at-

tempted to gain a solid foundation, the theory being that on account of the immense weight of the deposited material it will gradually settle to a compact foundation. The original plans contemplated a receiving reservoir holding 1,215,000,000 cubic meters, which would be adequate to hold the waters of a six-day flood, the longest continuous rainfall of the past ten years. By the new plan the reservoir will only hold 160,000,000 cubic meters, and the maximum discharge of the Chagres will fill it in twenty-seven hours if empty, but in the rainy season the dam will be well filled, and in case of an extended rainfall the dam will only be available for storing water for pumping purposes for filling of the upper summit level, while the unruly Chagres will still be uncontrolled.

From kilometers 45 to 23 the adjoining country is drained by the Chagres River, and in the event of a six days' flood its rise becomes enormous. In some cases the Chagres flowing in its original channel approaches within a few feet of the canal, when it is suddenly turned into a derivation channel, in some cases at right angles to its former course. Unless walls of masonry are constructed to protect these banks from the eddying effects of the stream, the Chagres will break through these mud banks and destroy the canal.

At any points between Gamboa and Colon, during the rainy season, the bed of the canal is lower than the Chagres, and is overflowed by it, completely stopping work on those sections. The sudden breaks in the surface shown on the profile are all crossings of the Chagres. Hence the small results shown for seven years' operations in this portion of the line; and it is apparent that until the deviations for the river on both sides of the canal are adequate to control the maximum drainage, the work on these lower sections cannot make substantial progress. One of the objects of the construction of the Gamboa dam is to control the flow of the Chagres, so that this part of the canal may be protected from its floods; but the cube of the the center of the Culebra cut, at kilometer 54, and exhibits the maximum amount of excavation done at any point on the line. The depth from the original surface to the bed of the sea level canal at this point was 354 feet. About 93 feet have been taken out, leaving 111 feet to be excavated to the bed of the upper lock level, as shown in the profile, or 261 feet to the bed of the sea level canal, through a length of 3,300 feet. The abandonment of the upper lock would add 30 feet in depth for a distance of 3⅛ miles; making the maximum cut 141 feet to the bed of the next lock level, and the excavation for the lock canal through the central mass between Paraiso and Haut Obispo, a distance of 5⅛ miles, would vary from 90 to 120 feet, apart from the 3,300 feet of the maximum cut. The profile shows at a glance that in general very little progress has been made in these difficult sections.

The surface width for a depth of 204 feet from the original surface to the bed of the upper lock level, at a slope of 1½ to 1, would be 750 feet. At this slope, which is the one now adopted, great difficulty is experienced from land slides, one of which may be seen in the upper center of the picture, on the face of the mountain. In consequence of this caving tendency, the terraces have already been forced backward and upward on the mountain side, which has necessitated the readjustment of the lower terraces, and this characteristic will render further widening necessary as the cut is deepened.

In the earlier excavation it was possible to dump the material on both flanks of the mountain, upon the same level, and about half a mile away, but on the lower terraces the haul is largely increased, the dumping grounds being outside the cutting, on the extreme right and left, and requiring long trestles, 50 and 60 feet high, reaching out over the adjacent swamps that are being rapidly filled up. As the excavation descends the length of haul from the center of the works increases in a heavy ratio.

A distance of a mile and a half, to kilometer 53, requires from 90 to 120 feet of excavation to the lock level, or 240 to 270 to the sea level, while at kilometer 47 the excavation is 15 feet below the level of lock No. 4, necessitating embankments, as is also the case at lock No. 3, at Gamboa.

The deviation of the Rio Grande is unfinished, rendering progress exceedingly difficult in the rainy season, as the river overflows the works. There was erected here a through truss iron bridge to carry the Rio Grande over the canal and unite it with the Rio Obispo on the opposite bank, but on account of the change from the sea level to the lock system, orders were sent from Paris in April to have the bridge taken down. This has been done, and it is stated at an expense greater than the original cost of the erection, and the parts are stored away to await further developments.

All the views given with this paper are reproductions of photographs actually taken upon the ground.

ON THE TESTING OF LARD FOR COTTON SEED OIL AND BEEF STEARIN.

By JOHN PATTINSON, F.I.C.

As much attention has recently been drawn to the prevalence of lard adulteration, I thought it would interest some of our members if I described briefly some of the methods by which these adulterations are detected and measured.

Although chemists have only lately been able to speak with certainty as to these adulterations, it has for some years been well known that lard, which ought to consist only of the fat of the pig, is very largely adulterated with cotton seed oil and beef stearin, and occasionally with water. Some of the American lard packers are the greatest offenders in this respect; but they are not the only offenders, for well authenticated

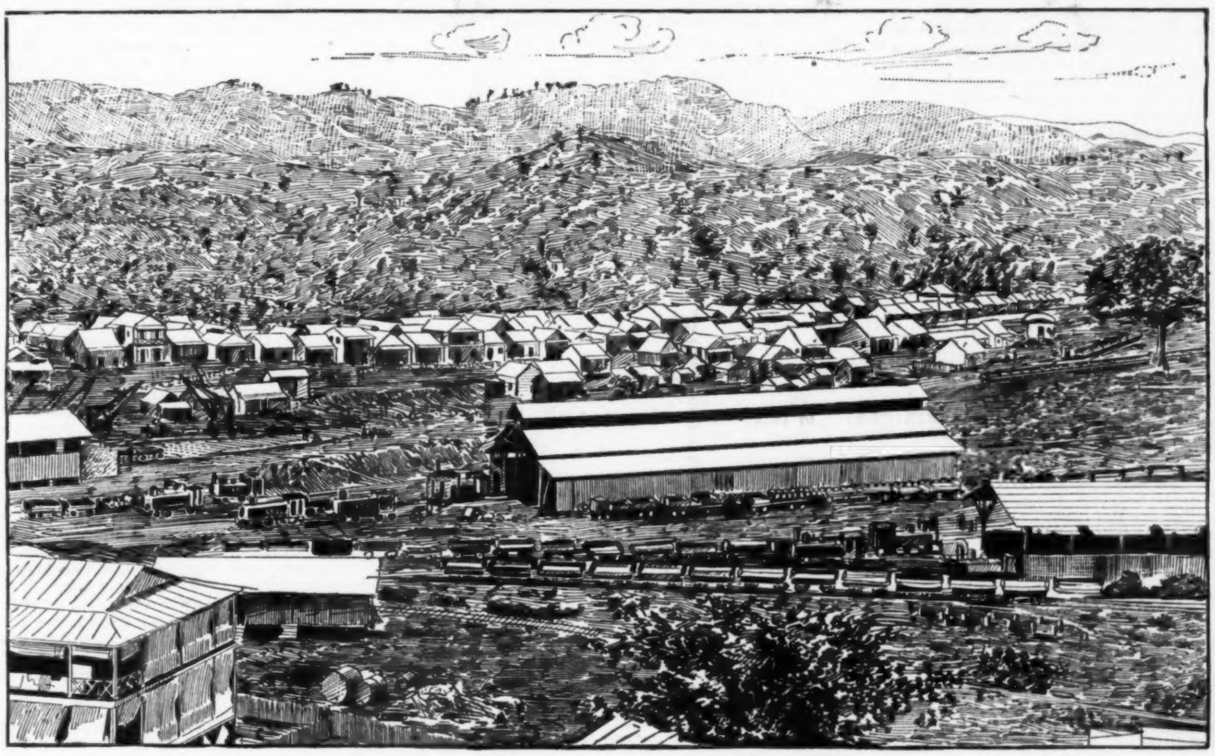


FIG. 24.—MACHINE SHOPS AT EMPERADOR.

deviations which have so far been made or proposed is only about one-quarter of the capacity required by the river in the height of the rainy season, the constructing engineers having adopted the view that the river will gradually enlarge the capacity of the deviations to its own requirements.

In April last I steamed from Colon up to kilometer 15, this length of canal being located in flat and marshy land, and the work has been accomplished by the Hercules dredges in discharging the material on either bank; but this work can only be carried on in the upper levels at enormous expense and trouble, as is shown by the lack of progress beyond kilometer 15 on the profile.

This open section of the Panama Canal (Fig. 19) has been the subject of much comment and congratulation on the part of interested persons, both here and in France. The contractors have used it to show the efficiency of their work, and the canal company's supporters have printed pictures of it, and elaborated its advantages for developing local trade and for use in transporting material and supplies to the works. In view of the uncontrolled flow of the Chagres, and the liability of this lower portion of the canal to damage from caving and silting, the policy of dredging it years before the whole can be completed, so as to render this part of use, would seem, to put it mildly, very questionable. The monthly cube of extraction reported at Paris has undoubtedly benefited largely by it, and pictures and descriptions of "sixteen finished kilometers of sea level canal" may have been of value at certain critical moments; but if the "open section" is ever to form part of an interoceanic canal, it will probably have to be all dredged out again some years hence, and the interest on the money paid for it would make a comfortable sum, which has been completely thrown away. It will be apparent to engineers that with the rest of the work in the state shown, this section should still be lying untouched, if the work as a whole was to be prosecuted economically, without regard to the necessity of impressing the gullible and ignorant.

THE GREAT CULEBRA CUT (Fig. 20).—This view, taken in April, 1888, shows the summit of the canal in

On the extreme left of the picture, in the lowest cutting in the foreground, the depth remaining to be excavated is over 100 feet to the lock level, or 250 to the sea level. In proportion with the deepening of the cut the hauling engines must overcome a heavy grade over an increasing vertical distance, and as the dumping grounds fill up, new ones must be found farther away.

It will be apparent that the excavation on the upper levels was accomplished with a minimum of labor and expense, and that as the cut descends the work will entail a rapidly increasing consumption of time and money in its execution.

The excavators chiefly employed here are of the endless-chain-of-buckets type, one or two of which are seen at work in the picture. These were satisfactory in working upon the sandy material of the isthmus of Suez, but they prove much less effective when attacking the hard pan and stiff clay of the Culebra. In connection with this plant are used Belgian 36-ton locomotives and the Everard iron dump cars, as seen upon the railway tracks in the picture, which was taken while work was going on at the usual rate, as we understand, and will enable those familiar with public works to appreciate how likely it is that the remaining work will be completed by 1890 or 1891, when this is what has been accomplished in the seven years, 1881-88.

Figs. 21 and 22 are from photographs of other portions of the Culebra cut.

THE EMPERADOR CUT (Figs. 23 and 24).—This view, taken in 1888, shows the canal line at kilometer 50·500, in the Emperador section, at the other end from Culebra of the great central level. The view is taken looking toward the Atlantic through the valley of Emperador, in the direction of Haut Obispo. On the extreme left may be seen the dumping grounds for the excavations, reached by rail, and already used to a large extent. In the left center are the houses and shops of the contractors and the huts for the laborers.

The work done thus far amounts to little more than the removal of the surface earth. The excavation still required along this immediate front for two miles is 60 feet deep to the lock level, over 210 feet to the sea level.

cases are known in which both English and Irish prepared lards have been found to contain similar adulterations.

The lard trade of America has assumed very large proportions. It was stated in evidence before a commission recently appointed by the United States House of Representatives to inquire into the question of lard adulteration, that about 270,000 tons are annually produced in America, upward of one-half of which is exported to other countries. Among the American lard packers there are several who prepare and supply only pure lard, but it was stated before the same commission by one of the largest producers that three-fourths of the American lard was packed by his firm and a few other large firms, and that these firms, "in order to keep up the quality and to meet the demands of the trade, added cotton seed oil and oleomargarine stearin" to their lard.

This lard is all branded and sold as "Refined Lard," "Pure Refined Lard," and other names calculated to lead the purchasers to believe that the lard is genuine pure lard. The cool way in which this perversion of the ordinary meaning of the word "refined" is defended is amusing. To the question, "Do you think that if there was only 20 per cent. of lard in your compound it would be right to brand that as refined lard?" the same witness answered, "Yes, sir. After we have been putting up lard for 25 years we claim to become expert in the manufacture of an edible lard for domestic purposes.

"If we consider that we can make an article that meets the demand of our trade, fulfills the wants of the trade, and is pure and wholesome and valuable, and can put in 50 or 60 per cent. of cotton seed oil and harden it with 20 per cent. of lard (beef stearin ?) to make it firm, it meets the demand of our trade. That is all they want. We know what they want better than they do themselves. . . . If we choose to say we are willing to put in our brand of refined lard only about 20 per cent. of lard, we consider it perfectly fair to do it."

The beef stearin used is a by-product of the margarine manufacture, and consists of the harder part of the beef fat, from which the oleomargarine has been sepa-

rated by pressure. Its price was recently about 36*s.* per cwt. The price of cotton seed oil was about 23*s.* per cwt. The price of lard was about 47*s.* per cwt. It will thus be seen that there would be a large margin of profit if a compound consisting of 50 or 60 per cent. of the cheaper cotton seed oil and beef stearin could be sold at the price of genuine lard; and this is probably the clew to the true explanation of the adulteration.

I do not enter into the question as to whether cotton seed oil and beef stearin are better or worse than pure lard. I do say, however, that such a compound ought to be sold under its proper description, and not passed off on the public as pure lard. When a purchaser wants and asks for lard he should be able to get it, and not be supplied with another and a cheaper article. The selling of such adulterated lard is also a serious injury to fair and legitimate lard packers who will only supply pure lard, but who are undersold by the makers of the adulterated lard.

To detect cotton seed oil and beaf stearin in lard, and to form an estimate of the quantity, the following tests are chiefly relied on: Some form of the nitrate of silver test for cotton seed oil, the microscopical appearance of the crystals formed from an ethereal solution of the lard to detect beef stearin, the iodine absorption equivalent, and the specific gravity. Useful information is also afforded by an examination of the color, taste, smell, and consistency of the lard.

The Nitrate of Silver Test.—This is based on the reducing action of cotton seed oil upon nitrate of silver, the reduced silver imparting a color to the lard. I have been unable to obtain constant or trustworthy results with this test as applied by Becchi (*see Analyst* of September, 1887), who I believe first proposed it, nor have I been more successful with the more complicated modification of Millian (*see Analyst* of May, 1888), which consists in applying the test to the fatty acids separated from the lard, nor with the several other modifications of this test which have been published. I obtain, however, very regular and certain results by adding an alcoholic solution of nitrate of silver to an ethereal solution of the lard. The method is as follows: 40 drops of the melted lard are placed in a test tube, and dissolved in 10 c. c. of ether, and to the solution 2 c. c. of an alcoholic solution of nitrate of silver (1 of nitrate of silver to 100 of alcohol) are added. The tube and its contents are left to stand for five or six hours in a place protected from light. If the lard contains cotton seed oil, the silver is reduced and imparts a maroon color to the solution—the depth of the color depending on the proportion of cotton seed oil the sample contains. By comparing this color with the colors produced in solutions of pure lard to which known percentages of cotton seed oil have been added, a close approximation to the amount of cotton seed oil in the sample can be obtained. Five per cent. of cotton seed oil in a lard can be readily detected by this method.

Test for Beef Stearin.—The positive evidence of the presence of this substance in lard is best obtained by examining under a microscope the crystals formed from an ethereal solution of the lard, as proposed by Dr. Belfield, of Chicago, and described in the *Analyst* of April last. For this purpose I use the ethereal solution of the lard mentioned in the last paragraph. Should crystals not form in the cooled solution, the cork of the tube is removed and a loose plug of cotton wool is substituted. The solution is then left to evaporate spontaneously until crystals form. It is sometimes necessary to redissolve the crystals, if they have been formed rapidly, by warming the solution, and sometimes adding a little more ether, so as to obtain crystals which have been slowly formed. Some of the crystals are then removed by a pipette, placed under a microscopic slide, and examined. The crystals of beef stearin form curved tufts somewhat of the shape of the short tail of a horse. The terminals should be pointed and hair like. Lard crystals are usually found in oblong plates, occasionally radiated, and have oblique terminals.

The Iodine Absorption Test.—This was first described by Hubl, whose method is given in the *Journ. Soc. Chem. Ind.*, 1884, page 641. According to my experience with lards of known purity, I find the iodine absorption equivalent of pure lard when tested by Hubl's method to vary from 57 to 63 per cent., and cotton seed oil to vary from 105 to 116 per cent. Were the lards to be examined for only mixtures of cotton seed oil and lard, it would be easy to arrive at a fairly close approximation to the actual amounts of each present from this test alone.

This, however, is never the case, as probably all lards which contain cotton seed oil have also had beef stearin added to make the mixture of a suitable consistency. Beef stearin has an iodine absorption of from 23 to 28 per cent., while beef fat, which may also have been used as an adulterant, has an iodine absorption of about 41 per cent. This, unfortunately, complicates the calculation of percentage amounts of impurity from the iodine absorption equivalents. Most of the adulterated samples, however, have hitherto contained cotton seed oil in such large quantity, and the iodine equivalent is so high, that a very substantial adulteration can be certified to without taking into account the effect of the beef stearin.

When, however, the amount of cotton seed oil is ascertained by the nitrate of silver test, a near approach to the amount of beef stearin also present can be calculated from the iodine absorption, after making allowance for the influence of the known quantity of cotton seed oil. If the lard is found to be a mixture of lard and beef stearin or beef fat without cotton seed oil, the calculation of the proportions of each is simplified; but as at present there are no known means of distinguishing beef fat from beef stearin in lard, it is necessary to calculate from the lower iodine absorption of beef stearin, and thus the amount of beef stearin may be understated. If the iodine absorption of such a lard be found to be 42 per cent., it will be safe to conclude that the lard contains one-half beef stearin and one-half lard, calculating the pure lard iodine equivalent at 61 and that of the beef stearin at 23 per cent., as $61 + 23 = 84 \div 2 = 42$.

The Specific Gravity Test is also a useful corroboration of the other tests, for cotton seed oil is higher in density than lard or stearin. It is customary to take the gravity at a temperature of 210° Fah. as compared with water at 60° Fah., and this is best done with a Westphal balance. At 210° Fah. pure lard has a gravity varying from 860 to 861, cotton seed oil is 868, and beef stearin 857. Lard adulterated with cotten seed oil is usually comparatively high in gravity. Some adulterated samples which have come under my notice have had a gravity of 863·5.

Mr. Jones, of Wolverhampton, has suggested in the *Analyst* for September last a qualitative test for cotton seed oil based on the stiffening effect which such oil imparts to a mixture of lard when sulphur chloride is added to it. This is a useful corroborative test.

Should the lard contain water, this is readily ascertained by the crackling effect produced when a portion of the lard is thrown on a red hot fire or into a red hot platinum dish. Its amount is determined by drying at 212° Fah. a known weight of the lard in a flat-bottomed straight-sided dish until it ceases to lose weight.

It is satisfactory to be able to state that in this district, at any rate, the cotton seed oil adulteration of lard is now seldom or never met with. This is owing to the prompt action which the authorities have taken in the matter, and also no doubt to the desire of wholesale dealers to avoid purchasing such lard now that they know of the existence of the adulteration. There are still many samples to be met with which contain very large admixtures of beef stearin or beef fat.—*Journ. Chem. Ind.*

STRUCTURE, ORIGIN, AND DISTRIBUTION OF CORAL REEFS AND ISLANDS.*

By Dr. JOHN MURRAY.

THE picturesque beauty of the coral atoll, seated amid a waste of troubled waters, with its circlet of living green, its quiet, placid lagoon, and its marvelous submarine zoological gardens, has long been celebrated in the descriptions of voyagers to tropical seas. The attempt to arrive at a correct explanation of the general and characteristic form and features of these reefs and islands has, for an equally long period of time, exercised the ingenuity of thoughtful men.

Coral reefs are the most gigantic and remarkable organic accumulations on the face of the earth. They are met with in certain tropical regions, and are huge masses of carbonate of lime, secreted from ocean waters by myriads of marine organisms. While the great bulk of the reef consists of dead corals, skeletons, and shells, the outer surface is clothed with a living mantle of plants and animals. This is especially the case on the outer and seaward face of the reef, where there are at all times myriads upon myriads of outstretched and hungry mouths, and not the least interesting questions connected with a coral reef are those relating to how these hungry mouths are satisfied.

It is to the power of these organisms of secreting carbonate of lime from sea water—building up and out generation after generation on their dead selves—that the coral reef owes its origin. So wonderful and unique is the result, that combination for a definite end has sometimes been attributed to these reef builders.

There is, however, another process ever at work in the ocean, in a sense antagonistic to that of secretion of carbonate of lime by organisms, which has much to do in fashioning the more characteristic features of coral reefs. This is the solution of all dead carbonate of lime shells, skeletons, and calcareous *debris*, wherever these are exposed to the action of sea water. As soon as life loses its hold on the coral structures, and wherever these dead carbonate of lime remains are unprotected by rapid accumulation or crystalline depositions, they are silently, surely, and steadily removed in solution. This appears to be one of the best established oceanographical facts, and any theories concerning the general economy of the ocean which fail to take account of this universal agency are most likely to be at fault. We know something about the rate of solution, probably more than we do about the rate of growth and secretion of carbonate of lime by the coral polyps.

It has been shown that the rate of solution varies with temperature, with pressure, and with the amount of carbonic acid present in the water. It is on the play of these two opposing forces—the one vital and the other chemical—and their varying activity in different regions and under different circumstances, that we rely for the explanation of many oceanographical phenomena, especially many of those connected with oceanic deposits and coral reefs. In some regions there may be more growth, secretion, and deposition of shell and coral materials than solution by sea water, and then there results the formation of coral reefs and vast calcareous deposits at the bottom of the ocean. There may be an almost exact balance between these processes. And again there may be more solution than secretion, as, for instance, in the red clay areas, which occupy the deepest parts of the ocean, and in some coral reef lagoons.

What is the nature of the foundations of these coral islands, surrounded as they sometimes are by an ocean miles in depth? Why have some elongated reefs, no lagoons? Why have most of the lagoons of the smaller atolls been filled up? Why is the circle of land or reef in the perfect atolls only, at most, a few hundred yards in diameter? What is the origin of the lagoon? What relation exists between the depth of the lagoon, its area, and the depth of the water beyond the outer reef? How has the dry land of these islands been formed, provided with a soil, a fauna, and a flora? These appear to be the chief questions that demand an answer from any theory of coral island formation.

These coral formations are essentially structures belonging to the great oceans and ocean basins. They are dots of land within the oceanic areas that might be compared or contrasted with the small salt lakes which are scattered over the surface of the continental lands. A rapid survey of some of the more general phenomena of the great oceans may, then, lead to a better appreciation of the problems connected with coral reefs.

The great ocean basins occupy over two-thirds of the earth's surface, and have a mean depth of over two miles. The central portions of these basins, called the abysmal regions, occupy about one-half of the earth's surface, and have a mean depression below the general level of the continents of over three miles. The abysmal regions are vast undulating plains, sometimes rising to less than two miles from the surface of the sea, and again sinking to four or five miles beneath it. Volcanic cones rise singly or in clusters from these great submerged plains. When they shoot above the level of the sea, they form single islands, like Ascension and St. Paul's Rocks, or groups, like the Azores, the Sandwich, the Fiji, and the Society Islands. As might have been expected, there are many more of these cones hidden beneath the waves than rise above them. When the Challenger sounded along the west coast of Africa, there was no suspicion that between her stations she was sailing over submerged cones. Since then, however, the soundings of telegraph ships have correctly mapped out no less than seven of these peaks between the latitude of Lisbon and the island of Teneriffe. The depths on the summits of these vary from 12 to 500 fathoms. On one of them, at 400 fathoms, two species of coral (*Lophohelia prolifera* and *Amphihelia oculata*) were growing luxuriantly. Throughout the ocean basins about 300 such submarine cones, rising from great depths up to within depths of from 500 to 10 fathoms from the surface, are already known, or indicated by soundings.

All the physical agencies at work above the lower limit of wave action tend to wear away and level down these cones, and thus to form banks. Graham's Island, thrown up in the Mediterranean in 1831, was 200 ft. in height and three miles in circumference, and was washed away in a year or two. The bank left on the spot, at first very shallow, has now 24 ft. of water over it. Instances similar to this historical example must often have happened in the great ocean basins. Again, the same agencies produce wide banks around volcanic islands by washing away and spreading out the materials of the softer rocks. Such banks, with depths of less than 60 fathoms, are found extending many miles seaward around some volcanic islands.

On the other hand, all the deeply submerged summits are continually being built up to the lower limit of wave action by the accumulation of the remains of animals which live on them and by the fall of shells upon them from the surface waters. In the Solomon Islands, Dr. Brougham Guppy has shown that there are upraised coral islands with central volcanic cones covered with thick layers of marine deposits. Christmas Island, in the Indian Ocean, is another instance, and similar deposits must now be forming over hundreds of submerged mountains. In this way are foundations prepared for the true reef-building species, which only flourish in the shallower depths.

The bulk of the water of the ocean has a very low temperature; it is ice-cold at the bottom, even under the equator, but on the surface within the tropics there is a relatively thin film of warm water, with a temperature of from 70° to 84° F. This film of warm water is much deeper toward the western parts of the Atlantic and Pacific than it is in the eastern, the reason for this being that the trade winds, which blow continually from the east, carry all the warm surface water to the westward, and draw up the cold water from beneath along the western shores of Africa and America to supply the place of that driven westward at the surface. Consequently, there is, at times, a very low temperature, and a great annual range of temperature, along these western shores. This is more clearly shown by the temperatures at 50 and 100 fathoms than by those at the surface. There are no coral reefs along the western shores of Africa and South America, a circumstance evidently connected with the low temperature, wide range, and, more directly, with the food supply consequent on these conditions. It appears to be a confirmation of this view that, on the eastern shores of Africa, about Cape Guardafui, from off which the southwest monsoon blows for several months in the year, cold water is also drawn to the surface, and there, likewise, are no coral reefs, though they flourish to the north and south of this region.

Coral reefs flourish in mid-ocean and along the eastern shores of the continents, or wherever the coasts are bathed by the warmest and purest currents of water coming directly from the open sea. If we except Bermuda and one or two other outlying reefs, where the temperature may occasionally fall to 66° or 64° F., it may be said that reefs are never found where the surface temperature of the water, at any time of the year, sinks below 70° F., and where the annual range is greater than 12° F. In typical coral reef regions, however, the temperature is higher and the range much less.

The food supply of the coral reef is derived from pelagic oceanic organisms, which exist in the greatest variety and abundance in the surface and sub-surface waters of the ocean. These consist of myriads of Algæ, Rhizopods, Infusorians, Medusæ, Annelids, Mollusks, Crustaceans, Ascidians, and fishes. A very large number of these creatures, within the tropics, secrete carbonate of lime from the ocean to form their shells and skeletons, which, falling to the bottom after death, form the vast oceanic deposits known as Pteropod and Globigerina oozes. It falling to the bottom, they carry down some of the organic matter that composed their living bodies, and thus are the animals which live on the floor of the ocean chiefly supplied with food. Here it may be remarked, incidentally, that the abundance of life at depths of even over two miles is very great. Our small dredges sometimes bring up over sixty species and hundreds of specimens in one haul—of invertebrates and fishes, exclusive of the Protozoa. The pelagic organisms above mentioned oscillate from the surface down to about 80 or 100 fathoms, probably that stratum of the ocean affected by sunlight, and they apparently descend further in regions where the stratum of warm water has a greater depth. Many of the forms rise to the surface in the evening and during calms, and sink again in sunlight and during stormy weather. It is in the evening and when it is calm that this swarming life is most vividly forced on the attention by gorgeous phosphorescent displays. The lime-secreting organisms, like Coccospheres and Rhabdospheres, Foraminifera, Pteropods, and other mollusks, are much more abundant, both in species and individuals, in the warmest and saltest waters than elsewhere. I have estimated, from tow-net experiments, that at least 16 tons of carbonate of lime, in the form of these shells, exist in a mass of the ocean, in coral reef regions, one mile square by 100 fathoms in depth. If we take this estimate, which I consider much below the reality, and suppose one-sixteenth of these organisms to die and fall to the bottom each day, then they would take between 400 and 500 years to form a deposit one inch in thickness. I give this calculation more to indicate a method than to give even the roughest approximation to a rate of accumulation of deposits. The experiments were too few to warrant any definite deductions.

* Lecture delivered by Dr. John Murray at the Royal Institution on Friday, March 16, 1888. Recently revised by the author.—*Nature.*

The great oceanic currents, moving westward at the rate of several miles an hour, bear these shoals of pelagic organisms on to the face of the reef, where millions of greedy mouths are ready and eager to receive them. The corals and other organisms situated on the outer and windward side of the reef receive the first and best supply; they are thus endowed with a greater amount of energy, and grow faster and more luxuriantly there than on other portions of the reef. The depth at which there is the most constant supply of this food is several fathoms beneath the surface, and there, too, the corals are found in most vigorous growth. It is only a relatively small quantity of this pelagic food that enters the lagoon, the corals that there struggle on in patches being largely supplied with the means of existence from the larvæ of reef-building animals.

So many observations were made during the Challenger expedition on the pelagic fauna inside and outside reefs that there is little, if any, doubt in my mind that the food supply is a most important factor in relation to the growth of corals in the different portions of a reef. Actual observations were made on the feeding of corals at a good many places, as well as numerous observations on the stomach contents. These observations have been confirmed by Alexander Agassiz.

It is as yet impossible to state in what form the lime which is secreted as carbonate in such enormous quantities by marine organisms exists in the ocean.

Dana, in "Coral and Coral Islands," considers it "unnecessary to inquire whether the lime in sea water exists as carbonate or sulphate, or whether chloride of calcium takes the place of these. The powers of life may take from the element present whatever results the function of the animal requires."

In connection with this question an interesting series of experiments are being conducted at the Scottish Marine Station, Granton, which go far to prove that the above hypothesis is correct.

The following table shows the average composition of sea water salts, the acids and bases being combined in the way usually adopted by chemists:

Average Composition of Sea Salt.

Chloride of sodium	77·758
Chloride of magnesium	10·878
Sulphate of magnesium	4·737
Sulphate of lime	3·600
Sulphate of potash	2·465
Bromide of magnesium	0·217
Carbonate of lime	0·343
	100·000

In the actual ocean water there are probably traces of every known element, and it is impossible to say what is the precise amount of the respective chlorides, sulphates, and carbonates present. Theoretically, every base may be combined with every acid, and the whole solution must be in a continual state of flux as to its internal composition. While the quantity of sea salts in a given volume of water varies with position, yet it has been shown by hundreds of analyses that the actual ratio of acids and bases—that is, the ratio of the constituents of sea salts—is constant in waters from all regions and depths, with one very significant exception—that of lime—which is present in slightly greater proportion in deep water.

The total amount of *calcium* in a cubic mile of sea water is estimated at nearly 2,000,000 tons. The amount of the same element present in a cubic mile of river water is nearly 150,000 tons. At the rate at which rivers carry down water from the land, it is estimated that it would take 680,000 years to pour into the ocean an amount of calcium equal to that now held by the ocean in solution.

The amount of calcium existing in the 40,000,000 square miles of the typical calcareous deposits of the ocean exceeds, however, that at present held in solution if we merely take them to have an average thickness of 30 ft.; and from this calculation we might say that, if the secretion and solution of lime in the other regions of the ocean be exactly balanced, and the calcium in the ocean remain always constant, those calcareous deposits of the thickness indicated would require between 600,000 and 700,000 years to accumulate. There is good evidence, however, that the rate of accumulation is much more rapid in some positions.

The lime thus carried down to the sea is originally derived from the decomposition of anhydrous minerals, and comes from the land in the form of carbonate, phosphate, and sulphate of lime—the carbonate being in the greatest abundance in river water. On the other hand, the sulphate of lime very greatly predominates in sea water, the carbonates being present in small quantity. We are not in a position to say whether or not the coral polyps take the whole of the material for their skeletons from the carbonates, as is generally believed, or indeed to say what changes take place during the progress of secretion by organisms.

In the greatest depths of the Pacific coral seas there is striking evidence of the solvent power of ocean water. Our dredges bring up from a depth of three or four miles over a hundred earbones of whales and remnants of the dense Ziphioid beaks, but all the larger and more areolar bones of these immense animals have been almost entirely removed by solution. In a single haul there may also be many hundreds of sharks' teeth, some of them larger than the fossil *Carcharodon* teeth, but all that remains of them is the hard dentine. None of the numerous calcareous surface shells reach the bottom, although they are quite as abundant over the red clay areas as over those shallower areas where they form Globigerina and Pteropod deposits. In consequence of the small amount of detrital material reaching these abysmal areas distant from continents, cosmic metallic spherules, manganese nodules, highly altered volcanic fragments, and zeolitic minerals are there found in great numbers. Almost all these things are found occasionally in the other regions of the ocean's bed, but their presence is generally masked by the accumulation of other matters. In some regions Radiolarian and Diatom remains are found in the greatest depths, and they too are subject to the solvent power of sea water, but to a much less extent than carbonate of lime shells.

As we ascend to shallower waters, a few fragments of the thicker-shelled specimens are met with at first; with lesser depths the carbonate of lime shells increase in number, until in the shallower deposits the remains of Pteropods, Heteropods, and the most delicate larval shells are present in the deposit at the bottom. This gradation in the appearance of the shells can be well seen in a series of soundings at different depths around a volcanic cone, such as has been described as forming the base of a coral atoll. There is no known way of accounting for this vertical distribution of these dead shells except by admitting that they have been dissolved away in sinking through the deeper strata of water, or shortly after reaching the bottom; indeed, an examination of the shells themselves almost shows the process in operation. It is rare to find any trace of fish-bones in deposits other than the otoliths.

These considerations, as well as numerous experiments in the laboratory, show that everywhere in the ocean dead or amorphous carbonate of lime structures quickly disappear wherever they are exposed to the action of sea water, and in investigating the evolution of the general features of coral reefs it is as necessary to take cognizance of this fact as of the secretion of carbonate of lime by organisms. At the same time, too much stress cannot be laid upon the fact that carbonate of lime, although markedly soluble in sea water in the amorphous form in which it exists in connection with (organic) life, becomes practically insoluble when after the death of the secreting animal it assumes the crystalline state.

In a paper read before the Royal Society of Edinburgh, embodying some of the results of his investigations on the solubility of carbonate of lime under different forms in sea water, Mr. Irvine remarks, "It is due to this molecular change that coral deposits, shells, and calcareous plants are able to accumulate in the ocean, ultimately to form beds of limestone rocks."

The first stage, then, in the history of a coral island is the preparation of a suitable foundation on the submerged volcanic cones or along the shores of a volcanic island or the borders of a continent. In the case of the atoll the cone may have been reduced below the level of the sea by the waves and atmospheric influences, or built up to the lower limit of breaker action by the vast accumulation of organisms on its summit.

A time comes, however, should the peak be situated in a region where the temperature is sufficiently high, and the surface currents contain a suitable quality of food, that the reef builders fix themselves on the bank. The massive structure which they secrete from ocean water enables them to build up and maintain their position in the very face of ocean currents, of breakers, of the overwhelming and outrageous sea.*

"Coral" with the sailor or marine surveyor is usually any carbonate of lime shell or skeleton or their broken down parts. "Coral" is used by the naturalist in a much more restricted sense: he limits the term to animals classed as Madrepores, Hydrocorallines, and Alcyonarians. The animals belonging to the first two of these orders comprise those included under the vague term of reef corals. Besides these, however, very many other classes of animals contribute to the building up of coral reefs and islands—such are Foraminifera, Sponges, Polyzoa, Annelids, Echinoderms, and Calcareous Algæ. The relative proportions of these different organisms in a reef vary with the region, with the depth, and with the temperature, but members of what are known under the term of reef corals appear always to predominate.

The animals of the true reef-building species resemble the common sea anemones in structure and size; the individual polyps may vary from the eighth of an inch in diameter to over a foot. Some of the structures built by colonies may exceed 20 feet in diameter.

There may be great variety in the appearance of submerged reefs as they rise from banks of a different nature, form, and extent, as, indeed, was pointed out long ago by Chamisso. There may be differences due also to the kinds and abundance of deep sea animals living on such banks, as well as differences due to currents, temperature, and other meteorological conditions.

From the very first the plantations situated on the outer edge will have the advantage, from the more abundant supply of food and the absence of sand in the water, which last more or less injuriously affects those placed toward the interior. Chamisso attributed the existence of the lagoon to the more vigorous growth of the peripherally situated corals of a reef, as compared with those placed toward the middle, and in this he was to a large extent right, but the symmetrical form of the completed atoll is chiefly due to the solution of the dead carbonate of lime structures.

The Great Chagos Bank illustrates the irregular way in which such a large bank of coral plantations approaches the surface. When these, however, reach the surface, they assume slowly a more regular outline, those on the outer edge coalesce, and ultimately form a complete ring of coral reef, and the lagoon becomes gradually cleared of its coral patches or islands, for, as the atoll becomes more perfect, the conditions of life within the lagoon become less and less favorable, and a larger quantity of dead coral is removed in solution.

The coral atoll varies greatly in size and form; it is usually more or less circular, horse shoe shaped, and may be one or over fifty miles in diameter. The breakers spend their fury on the outer edge, and produce what is known as the broad shore platform; but within, trees descend to the very shore of the lagoon, where there is quiet water, and a ship may often enter on the lee side of the atoll and find safe anchorage.

In this connection it is important to bear in mind the relation which exists between the periphery and the superficial area of the lagoon in atolls of different sizes. If the coral plantations which rise from the top of a submerged mountain have an area of one square mile, then on reaching the surface of the waves there will be a shallow depression in the center, owing to the more rapid growth of the outer edge. Such an atoll will have, if it be a square, four miles of outer reef for the supply of coral sand and other *debris*, and these being washed and blown into the one square mile of shallow lagoon, it is likely to become filled up, the result being a small island with dry lagoon, in which may be found deposits of sulphate of lime, magnesian and phosphatic rocks, and guano—all these testifying to the great age of the island and absence of subsidence in the region. It is only atolls with a diameter of less than two miles that thus become filled up. In other and larger plantations, rising from a more extensive bank, the conditions are very different. In this larger atoll—say four miles square—there is now only one mile of outer reef to each square mile of lagoon, instead of four miles of outer reef to the one square mile of lagoon in the smaller atoll. Only one-fourth of the detrital matter and food enters the larger lagoon, from the outside, per square mile of lagoon, and hence there is proportionately less living coral, the solvent agencies predominate, and the lagoon is widened and deepened. Growing seaward on the outer face and dissolving away in the lagoon, the whole expands after the manner of a fairy ring, and the ribbon of reef or land can never in consequence increase beyond a half or three-quarters of a mile in width, it being usually much less. I have recently made a very careful comparison of the latest Admiralty survey of the lagoon of Diego Garcia with the one made many years ago, and the result appears to me to indicate that the area of the lagoon has considerably increased in the interval, and the average depth is a little greater than formerly, although shallower in some places.

Atolls may occur far away from any other land, but it more frequently happens that they are arranged in linear groups, in this respect resembling volcanic islands. Extensive banks may be crowded with small atolls, like the Northern Maldives; or a bank may be occupied by one great and perfect atoll twenty to forty miles in diameter, like some of the Southern Maldives and the Paumotus. In some instances the large atolls appear to have resulted from the growth and coalescence of the smaller marginal atolls; especially does this seem to have been the case with the large Southern Maldives.

The outer slopes vary greatly in different reefs, and in different parts of the same reef. When there is deep water beyond, the reef very often extends out with a gentle slope to a depth of 25 to 40 fathoms, and is studded with living coral, the bosses and knobs becoming larger in the deeper water farthest from the reef, where there are great overhanging cliffs, which eventually fall away by their own weight, and form a talus on which the reef may proceed further outward. Occasionally there is a very steep descent almost at once from the outer edge. Thus, the deeper the water beyond, the more slowly will the reef extend seaward. In reefs with a very gentle slope outside, the corals are frequently overhanging at depths of 6 or 7 fathoms, for in these instances the lower part of the sea face of the reef is rendered unsuitable for vigorous growth, in consequence of the sand which is carried in by waves coming over the comparatively shallow depths outside. In these cases, lines of growing corals, or a submerged barrier, are sometimes met with in deep water some distance seaward from the edge of the reef.

As has been stated, the lagoon in many of the smallest atolls has been filled up, but this never appears to happen in atolls with a diameter of over two miles, unless there be distinct evidence of upheaval. In perfectly formed atolls—that is, those in which the reefs are nearly continuous throughout—the deepest water is found toward the center of the lagoon, and there is a relation between this depth and the depth of water beyond the outside reefs. In North and South Minerva reefs, in the South Pacific, where the outside depths are very great, there are depths down to 17 fathoms in the lagoons, which are apparently clear of coral heads. Here we may suppose that the central parts of the lagoon have for a long time been exposed to the solvent action of sea water, owing to the slow lateral growth of the reef as a whole. In the same regions the Elizabeth and Middleton reefs, which are about the same size, have only 4 or 5 fathoms within the lagoons, and the depths outside the reefs are, at the distance of a mile, mostly within the 100 fathom line, and sometimes less than 50 fathoms.

There are also many coral heads within the lagoons. Here we may suppose the atolls to be more recent, and to have extended more rapidly than in the case of the Minerva reefs. If the depths beyond the reefs be taken into consideration, then there is usually a direct relation between the depth of the lagoon and its diameter. The greatest depths, even in the largest atolls, do not exceed 50, or at most 60, fathoms; they are usually much less. In atolls which are deeply submerged, or have not yet reached the surface, which have wide and deep openings into lagoon-like spaces, this relation may not exist. In these instances the secretion and deposition of carbonate of lime may be in excess of solution in all parts of the lagoon. It is only when the atoll reaches the surface, becomes more perfect, and its lagoon waters consequently less favorable to growth, that the solution of the dead corals and calcareous *debris* exceeds any secretion and deposition that may take place throughout the whole extent of the lagoon; it is then widened and deepened, and formed into a more or less perfect cup-like depression, unless the lagoon be of small size and is filled up.

The whole of a coral reef is permeated with sea water like a sponge; as this water is but slowly changed in the interior parts, it becomes saturated, and a deposition of crystalline carbonate of lime frequently takes place in the interstices of the corals and coral *debris*. In consequence of the solution of coral *debris* and the redeposited lime occupying less space, large cavities are formed, and this process often results in local depressions in some islands, as, for instance, in Bermuda. At many points on a reef where evaporation takes place there is a deposition of amorphous carbonate of lime, cementing the whole reef materials into a compact conglomerate-like rock.

The fragments of the various organisms broken off from the outer edge during gales or storms are piled up on the upper surface of the reef, and eventually ground into sand, the result being the formation of a sandy cay or shoal at some distance back from the outer edge of the reef—the first stage in the formation of dry land.

The fragments of pumice thrown up into the ocean during far distant submarine eruptions, or washed down from volcanic lands, are at all times to be found floating about on the surface of the sea, and these, being cast up on the newly formed islet, produce, by their disintegration, the clayey materials for the formation of a soil—the red earth of coral islands. Just within the shore platform these pumice fragments are found in a fresh condition, but as the lagoon is approached they disappear, the soil becomes deeper, and

* Dr. Brougham Guppy says, "History can afford us no clew to the first appearance or the age of reefs; yet in the myths of the Pacific Islanders we find that the savage inhabitants of these regions regard the history of a coral atoll as commencing with the submerged shoal, which through the agency of God-like heroes is brought up by their fish hooks to the surface."—Paper, Vict. Inst.

the most luxuriant vegetation and largest trees are found close to the edge of the inner waters. The land is seldom continuous around the atoll; it occurs usually in patches. The water passes over the shallow spaces between the islets and through the deeper lagoon entrances, these last being kept open by the strong sand-bearing currents which pass at each tide.

The few species of plants and animals which inhabit these coral islands have been drifted to the new island like the pumice, or carried, many of them may be, by birds; lastly, savage and civilized man finds there a home.

There is no essential difference between the reefs forming fringing and barrier reefs and those which are known as atolls. In the former case, the corals have commenced to grow close to the shore, and as they grow outward, a small boat passage, and then a ship channel, is carved out between the reef and the shore by tidal scour and the solvent action of the water on the dead parts of the reef: thus the fringing reef may be converted into a barrier reef; or the barrier may be formed directly by the upward growth of the corals at some distance from the shore. In some instances the corals find a suitable foundation on the banks that surround islands and front continental lands, it may be, at a great distance from the coast, and when they reach the surface they form a distant barrier, which proceeds seaward, ultimately on a talus made up of materials torn from its seaward face.

If the foregoing considerations be just and tenable, then it would appear that all the characteristic features of coral reefs can be produced alike in stationary areas or in areas of slow elevation and subsidence, by processes continually at work in the ocean at the present time. Slow elevation or subsidence would only modify in a minor way a typical coral atoll or barrier reef, but subsidence in past times cannot be regarded as the cause of the leading characteristics of coral reefs. There are abundant evidences of elevation in coral reef regions in recent times, but no direct evidence of subsidence. If it has been shown that atoll and barrier reefs can be formed without subsidence, then it is most unlikely that their presence in any way indicates regions of the earth's surface where there have been wide, general, and slow depressions.

According to Mr. Darwin's theory, which has been almost universally accepted during the past half century, the corals commence to grow close to the shore of an island or continent; as the land slowly sinks, the corals meanwhile grow upward to the surface of the sea, and a water space—the lagoon channel—is formed between the shore of the island and the encircling reef, the fringing being thus converted into a barrier reef. Eventually, the central island sinks altogether from sight, and the barrier reef is converted into an atoll, the lagoon marking the place where the volcanic or other land once existed. Encircling reefs and atolls are represented as becoming smaller and smaller as the sinking goes on, and the final stage of the atoll is a small coral islet, less than two miles in diameter, with the lagoon filled up and covered with deposits of sea salts and guano.

It is at once evident that the views now advocated are in almost all respects the reverse of those demanded by Mr. Darwin's theory.

The recent deep sea investigations do not appear in any way to support the view that large or small islands once filled the spaces now occupied by the lagoon waters, and that the reefs show approximately the position of the shores of a subsided island. The structure of the upraised coral islands, so far as yet examined, appears to lend no support to the Darwinian theory of formation. When we remember that the great growing surface of existing reefs is the seaward face from the sea surface down to 20 or 40 fathoms, that large quantities of coral *debris* must be annually removed from lagoons in suspension and solution, that reefs expand laterally and remain always but a few hundred yards in width, that the lagoons of finished atolls are deepest in the center, and are relatively shallow compared with the depth of the outer reefs, then it seems impossible, with our present knowledge, to admit that atolls or barrier reefs have ever been developed after the manner indicated by Mr. Darwin's simple and beautiful theory of coral reefs.

THE COLLECTION AND PRESERVATION OF PLANTS.

EVERY one who is interested in natural history knows how useful it is to make collections. As the time during which a plant can be studied in a fresh state is very limited, the necessity of possessing, for such study, working tools and numerous works of difficult carriage makes the herbarium absolutely indispensable to the botanist. With certain care, however, it is possible to succeed in making collections of dried plants which closely resemble these same plants in a fresh state, and which at the same time permit of working at leisure and facilitate comparisons with duly labeled specimens that have undergone the same preparation. On an excursion, the botanist therefore has only to occupy himself with the collection of materials for study which he will utilize upon his return.

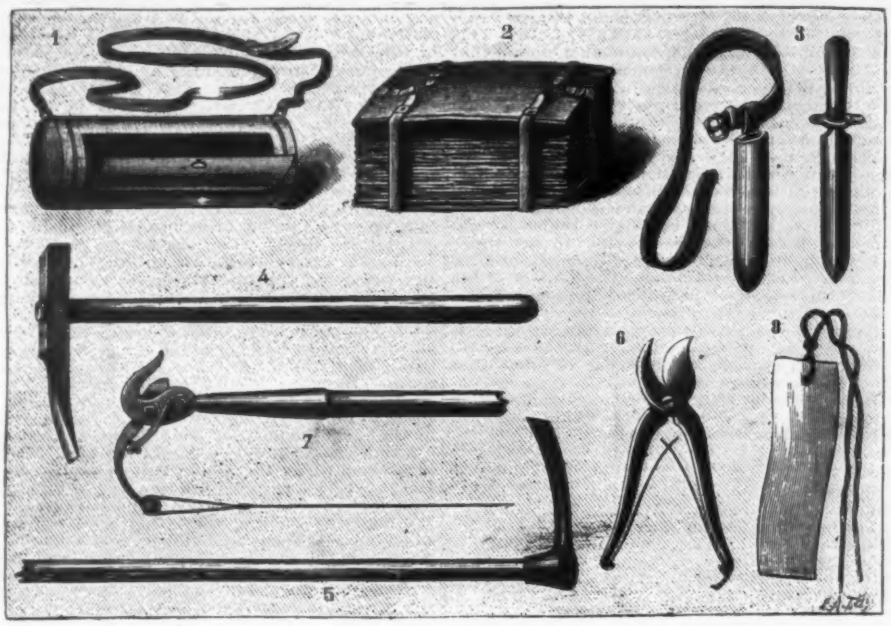
Of course, plants in a dried state no longer possess their natural aspect, but with a little experience, a person can easily restore this in his mind, and if, at the moment of collecting, he takes care to note certain characteristics that are necessarily modified through desiccation, it then becomes very easy to re-establish things.

It is of great advantage to the botanist to be able to preserve the plants that he has gathered and named, and this extraordinarily facilitates future work. If he makes a publication, he will be able to show the specimens that are the subject of it, and these types will always permit of rectifications by competent persons. It is due to the herbaria formed by travelers that we are gradually coming to be acquainted with the vegetation of the various parts of the world. Our large national museums receive these and hold them at the disposal of botanists, who describe their contents, and who can then draw up floras.

It thus becomes easy to seek, among the vegetable productions of each country, those that we may have an interest in studying. In this respect, horticulture and agriculture are absolutely tributaries of botany; so we should not like to see travelers omit from their labels any details as to the uses of useful plants and as to the processes of culture to which they are submitted. The herbarium is not only useful, but it is a pleasure to consult it. With every specimen there are connected remembrances which years cannot obliterate, and which give it a value so much the greater in proportion as there has been more difficulty in obtaining it.

Says Jean Jacques Rousseau: "All my botanical excursions, the various impressions of the place, the objects that have struck me, the ideas that have occurred to me, the incidents that have mingled therewith, all this has left me impressions which are renewed by the aspect of the plants collected in these same places.

"I shall never more see those beautiful landscapes, those lakes, those groves, those rocks, those mountains, whose aspect has always touched my heart; but now that I can no longer travel to these pleasing countries, I have merely to open my herbarium, and I am soon transported thither. The fragments of plants that I gathered there suffice to recall the beautiful spectacle to me. This herbarium to me is a journal of herborizations which causes me to begin the latter again with a new charm and produces the effect of a vision that paints them over again to my eyes."



FIGS. 1 TO 8.

1. Botanical Box. 2. Portable Press. 3. Bark Knife. 4. Cosson Pick. 5. Decaisne Pick. 6. Shears. 7. Apparatus for Gathering Branches. 8. Tag.

Herborizations.—In order to learn how to collect plants, one will do well to accompany some of the public excursions that are made every summer under the direction of several botanists. After a few excursions a person will be able to continue them well enough alone. In order to be a botanist, it does not alone suffice to familiarize one's self with the rare plants of the region where he dwells, and it is an error to think that public herborizations are made for the sole purpose of making localities known. As regards the study, commonest species have as much importance as others, and it is with these that it is necessary to begin. Therefore it is not necessary to make very lengthy excursions to begin with, and it is by degrees that one should extend the circle of his investigations with the object of finding things that he has not yet studied. It is preferable to collect but a few species at a time, so that they can be the more carefully examined on one's return home, and be properly prepared for the herbarium.

When a person is traveling, the conditions are changed. As one cannot carry his books with him, the wisest thing to do is to collect the largest number of specimens possible, to prepare them well, and to take notes that may be utilized whenever it is possible to do so.

FIGS. 9 TO 11.

9. Plants of small size. 10. Aquatic Crowfoots. 11. Plant bent.

The Botanical Box or Vasculum (Fig. 1) is a cylindrical tin box with elliptic ends, and usually painted green. It is provided with a leather strap that permits of its being slung over the back, so as to leave the arms free. It should, as far as possible, be made of the length of the paper that has been adopted for mounting the dried specimens upon. This is a guide in the collection of specimens, which it is then easy to gather of the proper dimensions. When these are too long to go into the box, they are bent at a sharp angle as many times as may be necessary, the stem being crushed at the spot where the bend is to be made.

If large collections are to be made, the vasculum will have to be of larger size. The usual dimensions are 20 inches in length by six in diameter. There are boxes with one or more compartments, but we like the other kind better, as we prefer to have a pocket box in which to put the small plants and delicate things that have to be carefully preserved. The aperture in the box should be large enough to allow the plants to be put in and taken out easily.

Instead of a botanical box, some persons use a temporary press (Fig. 2) to put their gatherings in. This consists of two pieces of strong cardboard or leather, between which are placed sheets of paper that serve to isolate the specimens. The whole is held in place by means of leather straps. This press permits of the easy preservation of species with caducous flowers, such as the anemones, flaxes, certain ranunculaceæ, etc. The beginning of the preparation that they undergo permits of having them in a perfect state, while they would have lost a portion of their organs had they been simply put into a botanical box. Unfortunately the press is unwieldy and difficult to carry. Another drawback resides in the use of the numerous straps necessary to hold it together, and which involves a considerable loss of time at each collection.

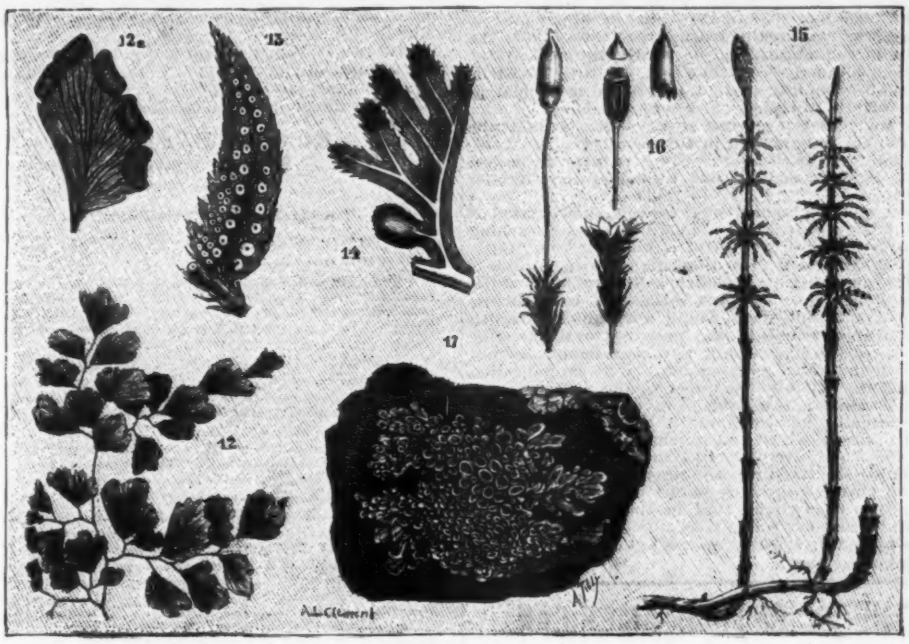
The Tools of Extirpation are numerous and varied, each having its merits and defects. For herborizing in sandy places a simple bark knife suffices. It has the advantage of being light and of being easily carried in a sheath that has been devised for it. This apparatus may be replaced by the poignard knife (Fig. 3).

For hard earth, and for plants whose roots penetrate the earth deeply, these tools are absolutely inadequate, and they should be replaced by the Cosson pick (Fig. 4), which is the apparatus generally adopted. It has the advantage of being very strong and also of being capable of entering the cavities of rocks, owing to the shortness of its handle. But the slight length of the handle renders it difficult to carry this tool, which weighs heavily in the hand. The Decaisne pick (Fig. 5), which certainly is not as strong, is, in this respect, much more convenient, for it may be used as a cane. It can be used also for pulling the branches of trees downward and for pulling in such aquatic plants as grow up a small distance from the edge of the water, etc.

Fig. 6 shows a good pair of shears for collecting branches of trees or shrubs, and spiny plants and

those too large to be collected entire, etc. In order to obtain specimens of tall trees, one will be obliged to have recourse to the apparatus shown in Fig. 7.

Collecting Plants.—The plants should be collected as entire as possible, so that they may show all the organs that can serve for their identification. But specimens, however properly they may have been collected, would be without interest were they not accompanied with carefully prepared tickets upon which are noted all the characters capable of modification through drying, or which cannot be found in a detached fragment of a large plant. It is necessary to indicate the aspect, that is to say, the form and dimensions, of the plant, and whether it is annual or perennial; the form and color of its flowers and its fruit; the station in which it is found (cultivated ground, woods, swamps, etc.); the nature of the soil; the altitude; the locality as accurately as possible; the date of collecting; and finally the uses of the plant. For the bringing together of all these data, it is necessary to have a memorandum book in which notes may be made in measure as the collection is done, a number being given to each plant that will be also affixed to the specimens through strong paper or parchment tags. The latter of these have the advantage of not being injured by humidity. To this effect, use may be advantageously made of tags provided with a string by which they may be firmly attached (Fig. 8).



FIGS. 12 TO 17.

12, 13, 14. Ferns. 15. Equiseta. 16. Mosses. 17. Lichens.

Plants of small size should be collected entire, along with their roots, which should be detached from the earth with the greatest care (Fig. 9). Where it is a question of parasites, such as the broomrapes, it is necessary at the same time to take up the host plant, the point of adhesion of the roots being sought for, so as to have the character of the parasitism in as evident a manner as possible. After freeing the roots of the earth by gently shaking them, the plants are ticketed and placed in the vasculum.

With the larger species, such as shrubs and trees, it is necessary to confine one's self to the gathering of either a summit or a branch provided with leaves, and with flowers or fruit. In this case it is necessary to gather carefully all the parts of the plant that exhibit differences, so that the whole shall recall as perfectly as possible the plant whence it is derived. With herbaceous species should be gathered a few of the radical or basal leaves, which often differ notably from those of the higher parts of the stalk. From trees and shrubs, a piece of the trunk or bark should be taken, and, in addition, the flower and fruit bearing branches, and branches of the first year, upon which the leaves are often more greatly developed.

FIGS. 18 TO 20.

18. Geological Hammer. 19. Cold Chisel. 20. Impression of Fossil Plant.

Certain plants are monœcious, that is to say, the same plant bears distinct male and female flowers. This occurs in the Indian corn, hazel nut, etc. Others are diœcious, the male and female flowers being borne on different plants. Such is the case with the date tree, the willows, etc. Here an endeavor should be made to find specimens showing the two sexes. Some plants flower before their leaves are developed. In this case, it is necessary to collect the flowers and return later to get the leaves. The hazel nut, the willows, the colt's foot, the colchicum, etc., are examples of such plants. With the willows, it is sometimes necessary to make even three gatherings, one of the flowers, one of the fruit and leaves when beginning to develop, and a third, of the mature leaves; and, as in this case it is easy to make a mistake and gather from another plant such specimens as are needed to complete those that one already has, we cannot too strongly recommend the marking of the trees that are to be visited in the future, either by removing a piece of the bark, or, better, by means of a wire passed around the trunk. Certain species lose their leaves at the moment of flowering. It is necessary to gather these in their various states of development.

Such plants as have flowers whose petals easily drop off, such as certain anemones, the flaxes, the aquatic ranunculuses (Fig. 10), etc., should be placed in a portable press; this is the only means of preserving them intact. When it is impossible to do otherwise than put them into the vasculum, it is necessary to select specimens provided with buds, which will be allowed to expand at home and then be put in the press. Specimens of climbing and other plants that are necessarily of large size should be bent at a sharp angle in order to bring them to the dimensions of the vasculum, and so that they shall occupy the least space possible (Fig. 11).

With palms, tree ferns, pandanuses, and other large plants, it will suffice to take a section of the trunk, and an entire leaf, which, if too large, may be divided into several segments, each numbered so that all may be the more easily united again later on. Large inflorescences are divided like the leaves; both may also be gathered entire, and then be dried by wrapping them in paper of large size in order to preserve them just as they are.

Fruits are to be gathered in as complete a state of maturity as possible. When they are large and fleshy, they should be put into alcohol on one's return from the excursion. For the small sorts, that are liable to be crushed in the box, it is well to have a small bottle full of alcohol to put them in immediately after they have been provided with parchment tags on which is written in lead pencil the number of the note book in which they are referred to.

We particularly insist upon the point that all the parts of the same plant should be ticketed in such a way that they may be united later on, and, to this effect, the simplest thing to do is to give them the same number.

The ferns (Figs. 12, 13, and 14), the lycopods, the rhizocarps, and the equiseta (Fig. 15) are collected in the same way as the phanerogams. The one thing essential is to select specimens provided with organs of reproduction. These latter are not always observed at first sight, yet they possess great importance in the distinguishing of species.

The mosses (Fig. 16), the liverworts, and the lichens are easily collected. They, too, should show the organs of reproduction. As regards the small terrestrial species, these should be taken up in a mass, a thin layer of earth being preserved to bind the whole together. The species that grow upon trees should be collected by removing the bark on which they exist. Finally, as regards the saxicolous, lichens, and liverworts, it will be necessary to break off a fragment of the rock upon which they grow (Fig. 17).

Fungi that have rather a dry consistency, such as the polyporei, clavarias, sphærias, etc., are easily collected, and the same is the case with such as live as parasites upon plants, and belong to the families Cæomacei, Mucedines, etc., it being merely necessary to select a fragment of the plant upon which they grow. As regards fleshy species, special care is required. They would quickly spoil if they were in contact with each other in the vasculum, and so before placing them therein it is indispensable to wrap them in paper or to put them in bags, so as to isolate them well.

The charas are gathered in the same way that the aquatic phanerogams, or rather the seaweeds, are. As the object of this article is rather to make known the precautions to be taken in the collecting and preparing of phanerogams, those who desire to study seaweeds especially will find all the information desirable in the excellent pamphlet published by Dr. Bornet, member of the Institute.*

Marine algæ should, as far as possible, be collected upon the rocks. Those thrown on the shore by the waves should not be preserved unless they are very fresh, and have not long been exposed to the air and to the rain, which deteriorates them. If they cannot be prepared at once, it is easy to preserve them by putting them into some vessel or other and sprinkling them with salt.

Drawings and photographs render collections of dried plants complete. A sketch, as bad as it may be, made in the note book, may have great value as giving an idea of the aspect of a tree, for example. Documents of this kind are generally wanting, and so we are almost always ignorant of the aspect of tropical trees.

The collecting of fossil plants should not be neglected. The study of these is assuming proportions that show the importance that they may have in the classification of species now living, and in the history of plants through the ages.

It will be necessary, therefore, to explore such quarries as may contain these fossils. By means of a strong pick, the collector may pull out the blocks of stone, from which, with a geological hammer (Fig. 18) and a cold chisel (Fig. 19), he will detach the parts to be preserved, and these he will render thin in order to make them more transportable (Fig. 20). Specimens thus prepared will have to be carefully wrapped up in paper and put into a geological bag (which then replaces the vasculum), in such a way that the surfaces that bear impressions shall be prevented from being injured by friction.—*La Nature.*

RAIN AND STORMS.

By H. A. HAZEN.

THERE is a very interesting article in this SUPPLEMENT, Nos. 697 and 698, entitled, "How rain is formed," in which Mr. H. F. Blanford, the noted India meteorologist, sets forth the most commonly accepted theory of rain formation. It may be well to carefully examine this question, and especially in the light of facts which have been developed in this country and not fully understood in Europe. It will be readily admitted that there can hardly be a subject of more vital interest to farmers and sea-faring men than this of rain and storms. Every effort should be put forth to discover their mode of formation and to brush away theories too often vague and inadequate to account for the facts. A man would be a great benefactor who could produce rain in time of drouth or enable a vessel, when beset, to escape the blast. The latter has been practically done, in general; but the former, though attempted again and again, has never yielded to man's efforts except in very rare and exceptional cases. It is possible that sufficient regard has not been had to the atmospheric conditions prevailing over a large region. Nothing can be more certain than the hopelessness of obtaining precipitation from the sky under certain conditions of pressure, temperature, wind, etc., but there are other times when the sky has a tendency to precipitation and when efforts to produce rain ought to succeed, if ever.

Perhaps the earliest theory of rain formation is that of Hutton, which ascribes rainfall to the condensation resulting from the mixing of two bodies of air of different temperature. It is now known that the rain in such case would be inappreciable. Nearly all our physical geographies, our meteorologies, and scientific papers assume that rain is caused in an uprushing current of air, greatly heated by the sun, in a certain rather definite position, or at the center of the storm, which is cooled by rising into the cooler upper atmosphere and thereby its moisture is condensed. It is also thought that the energy of our storms would be very quickly dissipated, were it not kept up and enhanced by the latent heat set free in this condensation, for it is very plain that if there were a steady inflow to the center of a storm, it would speedily fill up. This heat expands the air, thus producing a partial vacuum, into which more air rushes, and thus there is a continuous action.

It is of the utmost importance that we be able to express in concrete form and exact figures any theoretical effect. For example, we should know the amount of heating in the above case, the velocity of the uprush, the amount of heat set free, and so on. The expression, "Of great importance is the action of vapor, as a

* Instructions pour la recolte et la preparation des Algues. Cherbourg, 1856.

great storehouse of solar energy, acquired in the process of its evaporation, generally known as latent heat," is altogether too vague and indefinite. We should be able to enter this storehouse, to calculate, approximately at least, the amount of energy stored up, its effect upon the air, etc. An attempt has already been made by Prof. Mohn, of Norway, to make such computation, and this is so unique that it is transcribed here. He speaks of the Cuban hurricane of Oct. 5, 6, and 7, 1844: "In our storm cylinder the whole air mass was renewed thirteen times. In this instreaming air, in the three days, at least 473,500,000 horse power was produced, or fifteen times as much as all wind-mills, water-wheels, steam-engines, locomotives, man and animal power of the whole earth in the same time. Whence springs this unheard-of force? From the latent heat of the vapor which rushes up in the middle of the hurricane and is thereby condensed."

Without accepting the ordinary theories of condensation we may yet make a computation from assumed premises. In evaporating one grain of water from the land or ocean, the sun has rendered enough heat latent to raise one cubic foot of air 7° in temperature, and it is plain that if we recondense this vapor, just the same amount of heat will be set free and become sensible.

We may look at it in another way; suppose a cubic foot of saturated air has had a grain of moisture condensed without changing its temperature, just enough heat will be set free to re-evaporate the moisture, and everything will be exactly as at first.

Some one will ask, what will happen if we take the grain of moisture entirely away and not let it re-evaporate? Even if this were possible, of course the heat set free will raise the temperature of the air, and it will no longer be saturated, but there will be needed just that grain of moisture or some cooling to bring it into a state where condensation may begin.

It seems impossible to produce condensation except by cooling. Let us take two cubic feet of air side by side and saturated; whatever change is brought about in one we will transmit to the other. Cool one to 79°, the other will be heated to 81°. In cooling the first to 79° we have condensed ½ grain of moisture, and this has liberated latent heat enough to raise the second cubic foot to 83·3°.

We have, then, ½ grain rainfall, 1 cubic foot of saturated air at 79°, and another unsaturated at 83·3°. Suppose we mix these, we shall have two cubic feet of air at about 81° and unsaturated. This result is practically the same as we had before.

It would seem as though the action were exactly the same as in mixing two bodies of air of different temperature, in which case all are agreed no rain can occur.

In nature's laboratory there are no such sudden transitions of temperature as these, but the principles established here would apply to the slightest amount of cooling brought about in any conceivable manner. Almost a positive proof that no condensation sufficient to produce precipitation does occur in an ascending current at the center of a storm, is found in the fact that, in this country at least, there is little or no rainfall there, but the bulk of it occurs three hundred or more miles to the eastward.

It has been suggested that after the raindrop is formed, the rapid upper current carries it a long distance before it reaches the earth. This is a convenient hypothesis to support the original theory, but it will not help the drop which would fall by its own gravity within a few hundred feet.

Circulars dropped from a balloon at 10,000 feet, where there was a current of thirty miles per hour, have reached the earth within a mile. Often after a sharp stroke of lightning overhead there is a great downpour of rain, allowing a few seconds for the drop to fall.

It has also been suggested, in order to avoid this difficulty, that there are ascending currents wherever rain is falling, and not at the center of the storm alone. This is another convenient theory, but entirely untenable.

How can there be ascending currents anywhere except at the center? If these currents produce rain at irregular spots, then they should all the more produce it at the center, where they are most prominent.

This whole theory of an ascending current seems very weak. It would seem impossible to maintain any difference of density between contiguous air columns for any length of time in a frictionless medium. We cannot possibly consider that there are chimneys in the atmosphere or columns of air set apart by themselves. Any tendency to an unstable equilibrium would be at once corrected by the flowing in of the denser air to fill up the less dense places, and this would be all the more complete and rapid, the less the friction between air and air.

Balloon observations have repeatedly shown air strata of different temperatures, one above the other, with an insensible gradation between, but no interchange *en masse*. Observations on Pike's Peak, 8,000 feet above the plain, have repeatedly shown a sea of cloud beneath, but no uprush of air, though there was steady rainfall below.

It seems highly probable that rain is more or less a mechanical effect, and that our ideas regarding its condensation and the consequent liberation of latent heat must be changed. Does not the gradual approach to saturation of a vapor-laden air bring the molecules of vapor nearer together, or, at least, toward a condition where they can unite? In a saturated air it would seem as though the slightest cooling would dispose of a little of the latent heat, and then a few of the molecules would coalesce, as do globules of mercury, but without the liberation of latent heat. How can molecules unite as long as there is any latent heat present in either of them? If the latent heat were not all disposed of, it seems plain that the result would be a simple separation again into molecules and no mingling. This is an exceedingly important point. If we must draw out all the heat present before the union of the molecules, then this heat must be absorbed by the surrounding air, and, if this be heated, there seems to be no question but that the uprushing current would be quickly brought to rest.

The theory of storm formation, as now taught, presupposes that the whole action takes place at the center of an enormous atmospheric disturbance, outlined by the distribution of air pressure. It is toward this point that all the winds tend, radial in the outside region, but more and more tangential toward the center, and exactly so there. Here, then, there appears to be an enormous inflow of air, and it must be gotten rid of. It is thought that it can only rush upward, and in doing this it is rapidly cooled, the moisture is condensed, heat is set free, a vacuum is formed, and so on. All the facts point to the utter failure of this theory. Our storms are probably, while in the air, brought about by some force unrecognized as yet fully. These whirls are very similar to those in flowing streams, where there is no up and down motion, though to an observer the water seems to flow rapidly toward the center. This whirl is independent of temperature conditions in the surrounding air; in fact, Dr. Hann, of Vienna, has tried to show that the temperature even diminishes faster in vertical height in the center than at the edge, but this was due to an erroneous use of mountain observations. This whirl is also largely independent of the motion of the upper current, for that is much faster, and very rapidly leaves it behind. The theory that the upper part of the storm is continually tearing itself away from the lower and communicating its whirls through a frictionless medium down to the earth, destroys the whole idea of an ascending current, and hence is suicidal, as well as utterly worthless on other grounds.

The real center of severest storm action is not at the center of the isobars, but, in this country, at least, 300 or 400 miles to the eastward. Here we have the largest part of the rain, and all our tornadoes and thunder storms.

When we have learned what force is concentrated at this point, we have gone a long way toward learning the cause of our more violent storms. It seems probable that the action preceding our rains and storms is very far in advance of the storm center and even of the clouds themselves. Our first intimation, to be sure, is by the clouds, but these would very quickly vanish into thin air were not the way prepared for them. One thing is absolutely certain, our cirrus clouds are not formed by an uprushing current. Why should radiation into the sky from the upper regions at times bring about a condition suitable for the prolongation of clouds and at other times not? Why should there be a most oppressive heat and sultriness in the air at times when the sky is overcast, and then again with a perfectly clear sky the direct sun's rays have nothing like such an effect? Such questions can be put by the score, and we may hope that in the evening of this nineteenth century we may be able to take our instruments up to the cloud region itself and ferret out these seeming mysteries.

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